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End-of-degree project

**Degree in Industrial Organization Engineering**

# The roles of Industrial Ecology and Circular Economy: a literature review and a classroom application

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# Resum

Aquest projecte està dividit en dues parts principals. La primera part és una revisió profunda de la literatura científica, duta a terme per poder donar resposta a preguntes com "L'Economia Circular és una evolució del concepte d'Ecologia Industrial?", "Els conceptes d'Ecologia Industrial i Economia Circular, tenen aspectes en comú? Tenen diferències?" Després d'haver realitzat una compilació detallada amb nombrosos articles sobre el tema, els aspectes principals de l'Ecologia Industrial i l'Economia Circular han estat contrastades per les definicions i experiències de diversos autors. A més a més, aquest contrast també ha estat realitzat gràcies a una enquesta que es va enviar a diversos experts en el tema.

El propòsit de la segona part és el de fer més senzill l'aprenentatge del concepte d'Economia Circular i el seu abast i atributs. S'ha dut a terme a través d'un joc de taula didàctic, que ha estat utilitzat com a sessió final d'un seminari doctoral de la universitat de Pescara, Itàlia (Università degli Studi Gabriele D'Annunzio). Aquesta segona part s'ha dut a terme després de realitzar la primera i, per tant, després d'adquirir coneixements suficients sobre Economia Circular i les seves característiques.

# Abstract

This project is divided in two main parts. The first part is a review thesis conducted in order to answer questions, such as “Is the Circular Economy concept an evolution of the Industrial Ecology concept?”, “Do Circular Economy and Industrial Ecology have overlaps in their meanings? Do they have differences?” After a detailed compilation of numerous articles and papers on the subject, the main ideas of Circular Economy and Industrial Ecology are contrasted by the different authors’ definitions and experiences. In addition, this contrast is also made thanks to a survey that has been sent to some of the experts on the subject.

The second part’s main purpose is to make the Circular Economy apprenticeship easier for university students. It has been carried out throughout a didactic board game, which has been used as a final lecture of a doctoral course from Università degli Studi Gabriele D’Annunzio. This second part has been made after carrying out the research of part one and, therefore, after acquiring a sufficient knowledge of Circular Economy and its characteristics.

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# Glossary

Here is a list of words, symbols or abbreviations used in the project with their corresponding brief definitions. The existence of this section does not justify the omission of an explanation about these elements when they appear for the first time in the text.

- Industrial Ecology (also referred to as IE): study of the flows of materials and energy in industries, regarding also its impact on economic, social, politic or environmental facets.

- Circular Economy (also referred to as CE): economic strategy method used mostly to reduce consumption of resources and also the reduction of waste.

- Industrial Symbiosis (also referred to as IS): net of organizations that have processes or transactions in common, from which they all take profit.

- Environment: it is everything around us, a grouping of living and non-living things in which occur the physical or chemical interactions among them.

- Linear model: conventional production and consumption model, which consists in the extraction of the resources, the manufacturing of the products, the use of the products and the transformation into waste.

- Circular model: more recent production and consumption model which IE and CE are based on. Its main idea is the transformation of waste into new resources as input.

- 3 Rs: Reduce, Reuse, Recycle.

# 1. Aim and scope

In a constantly changing and evolving society, such as the one we are living in now, there are a lot of problems and different ways of adaptation. Not only due to technology and its own form of evolution, but also due to worldwide problems, such as climate change, the difficulty to obtain resources or the huge amount of pollution and waste.

Throughout history itself, a numerous amount of concepts and techniques to counter these matters and problems have appeared. It is thanks to these that society has been able to prosper in the way it has.

In this project, the main concepts that will be studied and put into context will be Industrial Ecology and Circular Economy.

The motivation on this project is to differentiate both concepts, as it is unclear if one is the "evolution" of the other, as well as to prove their similitudes or overlaps by carrying out a systematic review of the literature.

In order to find and operate with different and multiple articles and scientific journals, several databases have been used. Taking advantage of the studies in two different degrees (Industrial Organization Engineering and Business Administration), it has been possible to access the databases of two universities: Universitat Politècnica de Catalunya (UPC) and Universitat Oberta de Catalunya (UOC). In addition, due to the Erasmus period abroad, taken place during this course, it has also been possible to access the database of Università degli Studi Gabriele D'Annunzio (UdA), in Pescara, Italy.

Therefore, thanks to these different databases, the access has been granted to almost every sort of scientific literature found, and this has been very helpful in order to complete this project.

The main objective of this project, as it has been noted before, is to try to be able to answer in the most accurate way possible the question about which are the differences and overlaps between Industrial Ecology and Circular Economy. To sum up, the main objectives of this project are the ones below:

- Search and review the scientific literature regarding the topics of Industrial Ecology and Circular Economy.
- Compare the definitions of these concepts given by different authors.
- Analyze and describe chronologically the history of both concepts.
- Discover and identify the differences between Industrial Ecology and Circular Economy.
- Discover and identify (if any) the overlaps between the two concepts.

- Carry out a survey through a questionnaire to assemble the experts' viewpoints on the matter.
- Classify and analyze the experts' responses in order to obtain a conclusion.
- Contrast the conclusions on the review with the conclusions of the questionnaire.
- Use a didactic board game about Circular Economy in a university class and evaluate its impact in a generic way.

In an extended way, the objective of this project is to be able to help others in their research on both Industrial Ecology and Circular Economy from a humble perspective of a university student, but with the hope that someone can benefit from it in order to start the development of further research.

# 2. Methodology

## 2.1. Methodology for the review

The systematic review of the literature on the Industrial Ecology and Circular Economy concepts, as it has been mentioned in the section above, has been conducted consulting papers from scientific journals searched in databases. As it also has been said, there has been a consultation of three databases, from three different universities: Universitat Politècnica de Catalunya (UPC), Universitat Oberta de Catalunya (UOC) and Università degli studi Gabriele D'Annunzio (UdA).

i. UPC database

The methodology for the searches through the databases acted in according of the following steps for the research in UPC database:

A review of the literature was carried out through the UPC library website Bibliotecnica. The website includes a meta search engine (DiscoveryUPC), which allows to access different types of documents, such as books, conference proceedings and articles in journals, among others, if they are hosted by databases and online platforms the university is subscribed to.

Afterwards, the search had to be definite in order to be able to find and access the proper documents, so the author used an advanced search in which he selected the title, keywords, language or year, amongst other parameters. Right after, there were some other selections to filter the search, such as searching exclusively "Full text" and scientific articles and papers. Thanks to that, the final documents were notably reduced and their quality was better assured.

To select a document and locate it, the author had to click it and, after reading the subject and summary, as well as seeing the year, author, etc., select the link in which the "Full text" was located in order to download the article/paper/journal from its site.

After that, by using the computer program Mendeley, the author was able to classify the documents and access them in an organized way, as well as extracting the references more easily.

This database can be accessed from this URL: https://bibliotecnica.upc.edu

ii. UOC database

Since it was a different website from the UPC database, the boxes that were to be clicked and the links that were to be accessed were obviously distributed in a different way, although the procedure followed in order to extract data from the UOC database was exactly the same as the data extraction from the UPC database.

This database can be accessed from this URL: http://biblioteca.uoc.edu/ca/

iii. UdA database

For this database, the extraction of the data had to be accessed through a Proxy access to the university library. After configuring it, the procedures followed were similar as the ones followed on the two other databases, aside from the websites' differences of style and format. Even so, as well as with the UPC and UOC, there is a more visual explanation on the research in Appendix 1.

This database can be accessed from this URL: https://biblauda.unich.it

Eventually the results yielded by the three library searches were very similar, so, in the end, the only database used for the literature review has turned to be the UPC database. This way, the search was also much more simple.

Therefore, as the content that needed to be accessed was purely conceptual, the first step to find results was to search the determined concepts in the search bar of the database searcher.

The language of the literature has been exclusively in English, since most researchers publish directly in this language for reach purposes.

For the search of the articles about Industrial Ecology, the process followed in order to carry out the search and selection of the articles was the following:

- First, the author carried out the search of "Industrial Ecology" included in the title of the document, and this search had a total of 2.683 results.
- Then, the author applied an advanced search allowing only the results of "Article/Chapter online". The results were only reduced to 2.658.
- Afterwards, the filter applied to diminish the results was the "Full Text" and, after applying it, the results were reduced to 1.891.
- The number of documents to review was still too high, so a filter of time period from 2014 to 2019 was applied, reducing the results significantly to 434.
- For a last filter, the author selected the keyword "Concept" with the Boolean operator AND, so that it was clear that the search was about the concept of Industrial Ecology itself. This resulted in a final results list of 22.
- The search results were organized by relevance, rather than date.

After reading the title and abstract from these results, the chosen ones were 7. All these articles were read and revised and 12 additional references from these 7 articles were also reviewed to carry out the final project.

For the search of the articles about Circular Economy, the process to search and select the articles was the following:

- First, the author carried out the search of "Circular Economy" included in the title of the document, and this first search had a total of 12.213 results.
- As the author just wanted to access to articles, rather than conferences or books, the advanced search option was selected, as well as the format of "Article/Chapter online". The results were reduced to 8.739.
- The results were still too numerous to be revised, so yet another selection was conducted: the "Full Text". After this, the results were reduced by almost 2.000, with a total of 6.936.
- Afterwards, the author applied yet another filter, the temporal one. He changed the temporal period from "Unfiltered" to a time period of the last five years (from 2014 to 2019), reducing the total number of results just by 700, with a total of 6.239.
- Finally, the author searched for reliable sources and he found out that "Scopus" database was one of the best, so this was the next filter. After applying this last filter, the search results were widely reduced to 1.168.
- For a last filter, the author selected the keyword "Concept" with the Boolean operator AND, so that it was clear that the search was about the concept of Circular Economy itself. This resulted in a final and much more reduced search of 38 articles.
- The search results were organized by relevance, rather than date.

After reading the title and abstract from these results, the chosen ones were 7 as well. All these articles were read and revised and 17 additional references from these 7 articles were also reviewed to carry out the final project.

For both Industrial Ecology and Circular Economy literature, the time filter has been tightened on the last 25 years (from 1993 to 2019). This was not applied in the search of the first articles (since it was from 2014 to 2019), but afterwards, when cited literature in those articles was subsequently reviewed.

After developing this review, the chart below (see Table 2.1) summarizes the articles taken into account for the literature review.

| | 1st search | Final refined search | Articles used |
|---|---|---|---|
| Industrial Ecology | 2.683 | 22 | 19 |
| Circular Economy | 12.213 | 38 | 24 |

**Table 2.1. Literature review summary**

Even though a total of 43 articles have been read and reviewed, not every one of them has been cited in the references of this end-of-degree project, since, in the end, some articles' content was repeated or unneeded.

## 2.2. Methodology for the questionnaire

In order to prepare the survey that has been sent to numerous experts on Industrial Ecology and Circular Economy, some tips and steps have been followed.

First of all, the emails from the experts have been obtained revising the published articles that have been checked during the research. In scientific articles, there is usually a type of contact information that allows the reader to contact with the author(s) and it is normally an email. These articles have been published by experts from all over the world, especially from Europe, so the participants of the survey are from various places.

Meanwhile, the survey has been created following Harrison's main steps and tips on how to conduct a survey (Harrison, 2007):

- Do not reinvent the wheel: check if someone has already done the same survey, so that it isn't necessary to repeat it.
- Pre-test the survey: try the survey before sending it, not just with the creator, but also with others.
- The mode of the survey has to be well defined and carried out only in one way (it was chosen to be with Google Forms in order to make it easier to both ask and answer).
- Keep questionnaire short and the questions in the right order, so that the previous question does not impact the next answer.
- Etc.

Afterwards, when the survey had already been created, the email addresses were collected and written in a word document. A message with the explanation on the project was sent to the selected experts via email, along with the link to the survey.

This email was sent to 76 experts on June 30th, 2019. Further on, a reminder email was sent on July 8th, and a final email on August 20th. Up to 41 had replied by August 26th, so that was the number of people that was taken into account for the data analysis in the end. The emails sent can be found in the Appendix 2.

In order to manage and organize the data collected from the questionnaires, the author created a Microsoft Excel sheet. After that, it was easier to extract the knowledge and conclusions from them.

In the content of Appendix 3 are some screenshots about the questionnaire, which can also be consulted through this link https://forms.gle/2XVoiC4VQRFjUv7b7.

## 2.3. Methodology for the board game

Besides the definition, description of history and comparison between Industrial Ecology and Circular Economy, as it has been mentioned in the "Objectives" chapter, there has also been the introduction of a board game in a university session.

The board game is called "In the Loop" and Katie Whalen, a PhD student researching business models for reuse at Lund University, developed it. She developed it as her graduation research project and the game is now available worldwide and can be used by educators and practitioners. There is a website (https://intheloopgame.com) for further information about Whalen and "In the Loop".

Before the implementation of the game in a class of students, two sessions of preliminary tests were conducted: on May 28th, 2019, with professor Alberto Simboli, Dr. Raffaella Taddeo and the author of this project and also on May 30th, 2019, with the same group and the addition of the project supervisor Andrea Raggi.

On June 21st, 2019, there was a seminar conducted by the end-of-degree project supervisor, professor Andrea Raggi, Dr. Ioannis Arzoumanidis and the author of this project. The seminar was given as the final lecture of a 16-hour doctoral course in Industrial Ecology and lasted for 3 hours approximately. Its content was mainly to implement the game "In the Loop" in a class for academic purposes, as well as a brief debate after the game. There was also a questionnaire, which was later used to classify the data in this project.

The group of students chosen for the implementation of the board game was constituted by 8 present doctorate students, who came from different degrees. This meant that some of them had good knowledge of Industrial Ecology and Circular Economy and some others had not. In addition, in this doctorate course, there were two students from other countries, who did not have Italian as their mother tongue.

# 3. Definitions, history and limitations of Industrial Ecology and Circular Economy

In recent times, with the emergence of Global Warming, the massive reduction of Earth's resources, the increase of waste and pollution all over the world, among other things, there has appeared also a tendency trying to cope with these factors.

There have been different concepts that have emerged throughout the years and their main goal is to diminish some of the factors described before. Two of these concepts are Circular Economy and Industrial Ecology.

As both concepts are related to the efficiency on industrial and economic factors, as well as the objective of being environmentally friendly, their definitions, in order to differentiate them are recommended.

## 3.1. Definition and description

### 3.1.1. What is Industrial Ecology?

The name itself from Industrial Ecology is formed by two words. Industrial Ecology is *industrial*, because it is focused on the design of the products and the characteristics of the processes. It is *ecological* in a sense that it is based on natural ecosystems and their functioning and also because "it places human technological activities in the context of the larger ecosystems that support it", along with the examination of the sources from the resources, the materials used and the sinks that "absorb" waste (Ayres *et al.*, 2015).

Industrial Ecology (IE) is not an academic discipline, but a scientific concept or field, a way of thinking or a strategy that can be applied in different facets overall in society (Brattebo, 2002). It also includes tools, methods and principles relevant to business management (Sullivan, Thomas and Rosano, 2018).

Industrial Ecology can be defined as a sort of study with the aim focused on understanding how the materials and energy flows circulate (Saavedra *et al.*, 2018) (see figure 3.1). It tries to understand the functioning and regulation of the industrial ecosystem, as well as its interactions with the biosphere, so that afterwards it can be restructured imitating the functioning of natural ecosystems (Erkman, 2002). It is a framework with the aim of guiding an industrial system to a transformation into a sustainable basis (Lowe and Evans, 1995).

IE aims at changing the lineal flow of materials in industrial systems into a pure circular one (production with zero waste (Lippke, 1995). IE defines three different stages: stage 1 is the linear flow of materials (unlimited resources and unlimited waste), stage 2 is a semicircular flow (limited inputs and limited waste) and stage 3 is the ideal industrial functioning, in which there is only renewable energy as input and no waste (see figure 3.1).

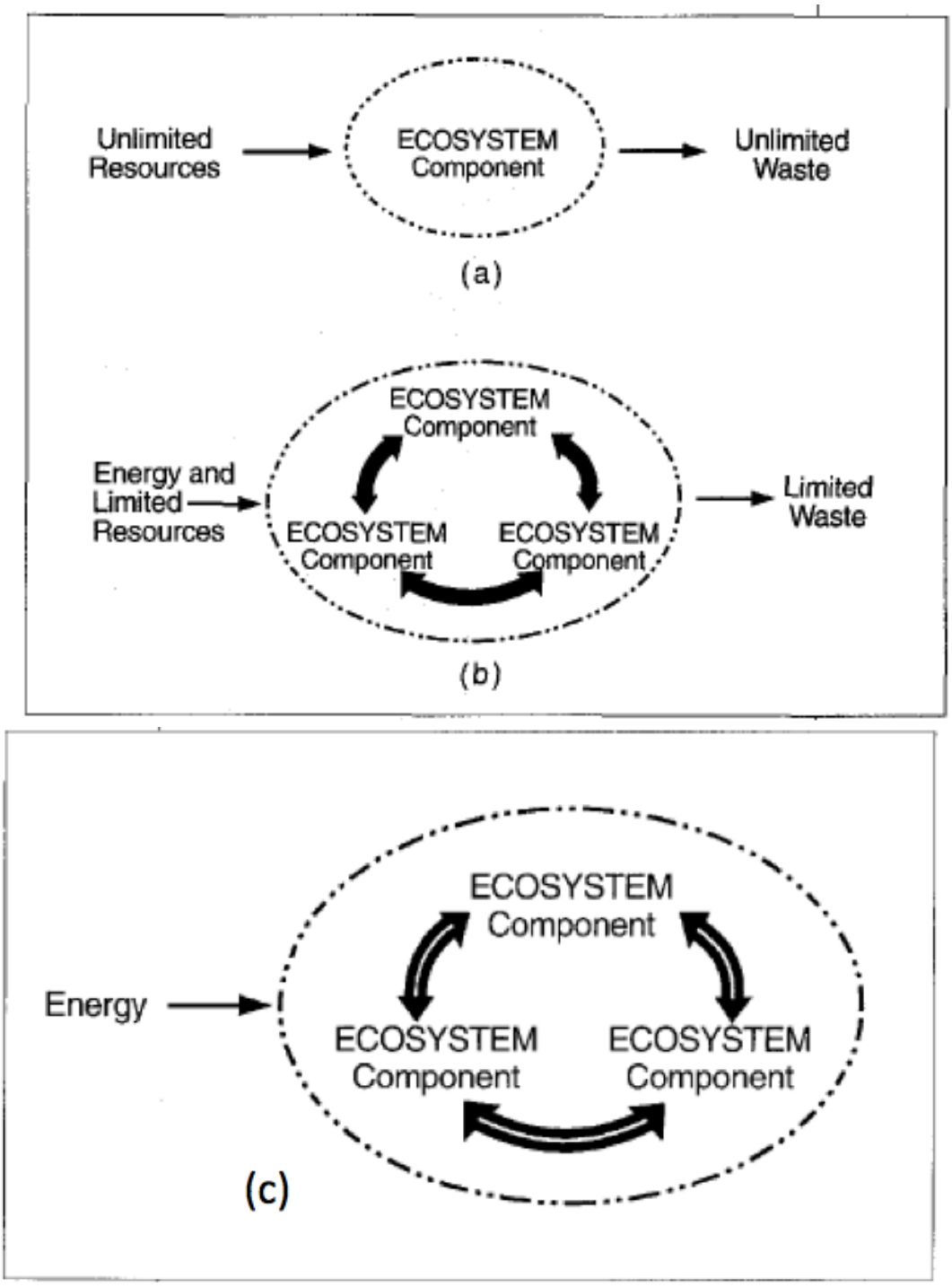


**Figure 3.1. Materials flows (a) Linear (b) Semicircular (c) Circular (Source:** Graedel, Allenby and Linhard, 1993**)**

It can also be defined as a "new" synthesis of the interaction between humans and the environment, whose goal is to "copy" nature in terms of cycling and recycling products made by humans (Kangas and Seibel, 2018).

Schiller et al. (2014) define it as the study of the flows of materials and energy in the industrial scope, but also the effect it has on different facets, such as the environment, the economic, politic and social influence, and the use of the resources that flow (White and Boyce, 1993).

Its aim is to optimize the management of the resources increasing the interactions which take place between different stakeholders in the same geographic area, for example in port cities, where resource management is very important (Cerceau *et al.*, 2014). These interactions are called Industrial Symbiosis (IS) (see an example from Taranto, Italy in Figure 3.2).

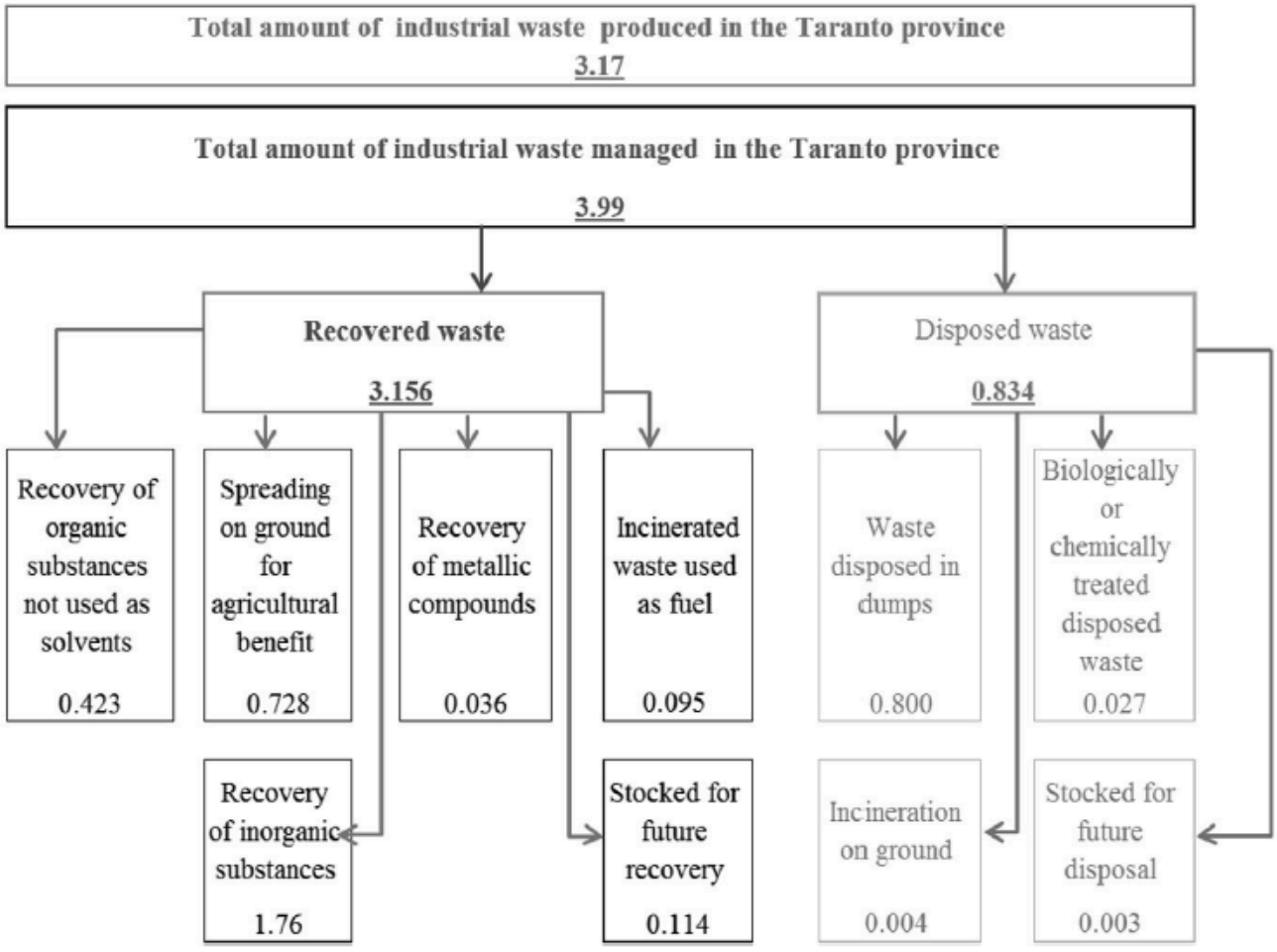


**Figure 3.2. Graphic example of IS in Taranto (Source:** Notarnicola, Tassielli and Renzulli, 2016**)**

Industrial Ecology can operate in different levels of scale, such as firm level, inter-firm level or global level (Hao *et al.*, 2017) (see Figure 3.3).

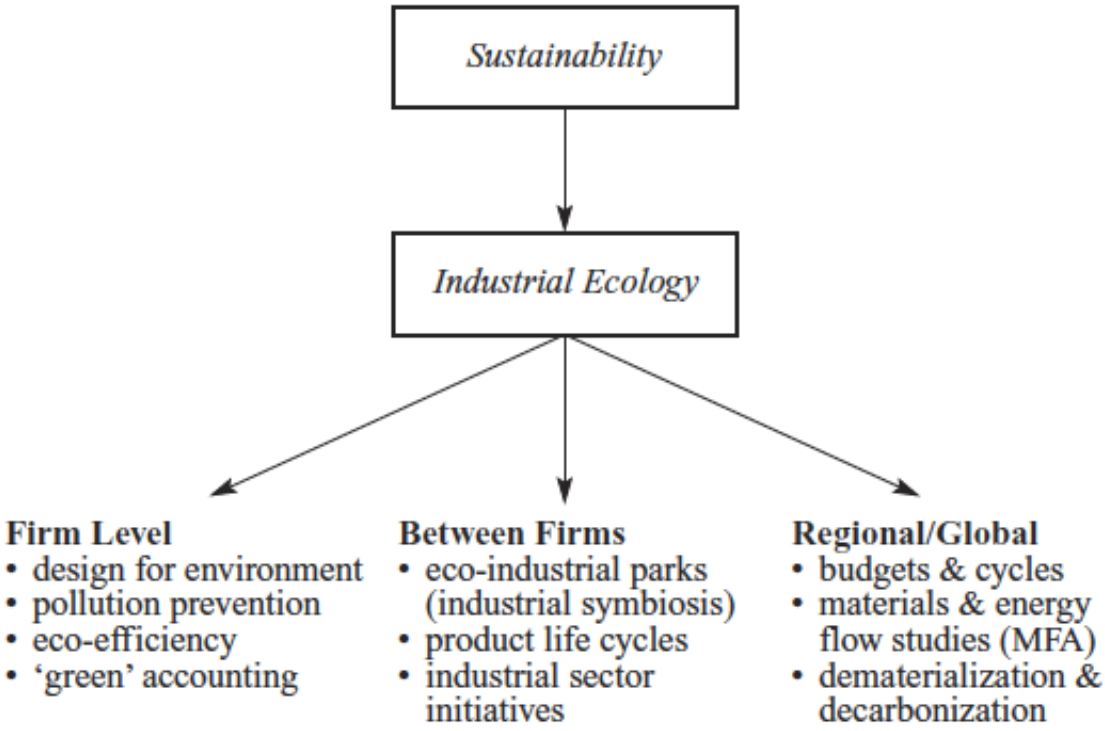


**Figure 3.3. Characteristics of different levels of scale (Source:** Ayres *et al.*, 2015**)**

For decades, it has been considered as a concept, which can provide methods and practices that connect the traditional business practice and a more sustainable development (Sullivan, Thomas and Rosano, 2018). It has been used successfully in engineering context. It has a strong focus on innovation of products and business models and opportunities. The goal of IE is also the efficient use of resources and energy.

As a summary, the areas in which IE focuses are (Ayres and Ayres, 2002):

- Dematerialization and eco-efficiency.
- Consideration of production and consumption realms.
- Redefinition of the role of business.
- Technology innovation.
- Systems thinking.
- Application of biological analogy in which industrial systems are reimagined as complex industrial ecosystems existing in symbiosis with larger social and biophysical environments.

### 3.1.2. What is Circular Economy?

The concept of Circular Economy itself has its name because it resembles a circle in its process, as it favors the cycling of materials and energy flows within the economic system. It can be defined as an economic strategy, since it tries to confront the current idea of a linear model (see Figure 3.4) for a "take-make-dispose" (Jeanes, R. & Lindsey, 2004) into a circular one. In that way, it is a circle that keeps repeating itself, from the acquisition of resources to the use and discard of the products and reuse of them to fabricate new products. (Korhonen, Honkasalo and Seppälä, 2018).


Figure 3.4. Linear Economy sketch (Source: https://talkintrashwithuhn.com/2017/06/07/trash-to-treasure-accelerating-the-circular-economy/)

It is a topic that has been gaining audience and importance lately, even becoming trending in recent times and, of course, due to its complexity and transversal nature, "there is no single definition of Circular Economy, having been defined in numerous ways" by different authors (Ruiz-Real *et al.*, 2018).

Circular Economy is a model described by an improved system of production and consumption of goods and materials ruled by a closed loop (see Figure 3.5) (Blomsma and Brennan, 2017). The essence of this concept is to innovate business models that shift from single transactions to multiple through business models (Nußholz, 2017). Its main point is to capitalize on material flow recycling, as well as to balance the growth of economy and the development with the use of resources and its impact on the environment (Winans, Kendall and Deng, 2017).

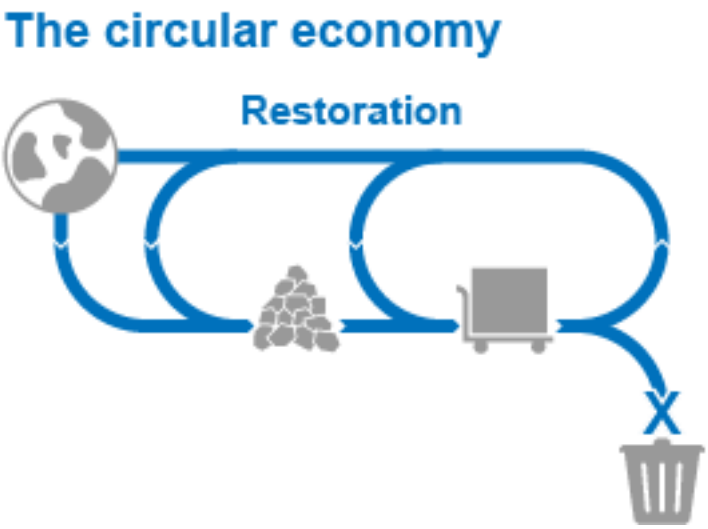


**Figure 3.5. Circular Economy sketch (Source: https://talkintrashwithuhn.com/2017/06/07/trash-to-treasure-accelerating-the-circular-economy/)**

The Circular Economy is therefore contrary to the linear model and, this new model is universally valued for its efficiency in the utilization of ecologic resources, the reduction of environmental pollution and the economic growth (Lakatos *et al.*, no date).

According to Bocken, Ritala and Huotari (2017) CE's premises are closing loops, for the recycling of waste after consuming the product, and slowing loops, for the retention of the product's value for as long as possible throughout repair, maintenance or remanufacturing.

Circular Economy is a restorative, regenerative industrial system (Ghisellini, Cialani and Ulgiati, 2016) that is not only focused on the acquisition of resources and their use, but also in the reduction and utility of waste (Parida *et al.*, 2019). The idea of Circular Economy stimulates new business opportunities by reducing negative environmental impacts (Korhonen, Honkasalo and Seppälä, 2018).

One of the objectives of Circular Economy is to restore the biogeochemical cycles, such as the oxygen or carbon dioxide from the atmosphere or the water cycle, among others, all altered because of human activity (Murray *et al.*, 2017).

After a long review on 114 different definitions of Circular Economy in scientific articles (Kirchherr, Reike and Hekkert, 2017), the concept of Circular Economy is most frequently described as the combination of reduction, reuse and recycling activities. Therefore, it is a development model with the aim of minimizing the impact of human activities regarding the 3 Rs (Scarpellini *et al.*, 2019) in order to "maintain the utility and value of products, components and materials" (Ellen MacArthur Foundation, 2015) for as long as possible. It is seen as a way to counter the current and urgent environmental problems through these 3 Rs (Liu *et al.*, 2017).

The main features of Circular Economy include the 3 Rs, but sometimes, there are references that talk about the 6 Rs (reuse, recycle, redesign, remanufacture, reduce and recover) (Geisendorf, 2017).

The Ellen MacArthur Foundation defines it as a restorative and regenerative economy with the objective to keep products and materials at the highest utility and value possible, distinguishing between technical and biological cycles.

It can also be referred to as a globally accepted solution (Prieto-Sandoval *et al.*, 2018) that has the scope to generate economic prosperity, protect the environment and prevent pollution (Prieto-Sandoval, Jaca García and Ormazabal Goenaga, 2016).

The Circular Economy approach emphasizes improvements, such as the material or component reuse, their repair, remanufacturing and the use of cleaner energies like biomass, solar, wind power and whichever that improves the product value chain in an environmental way (Korhonen, Honkasalo and Seppälä, 2018).

As a more specific approach, the order of product and material exploitation is headed by reuse and repair, then remanufacturing, afterwards for the reutilization of raw materials, the for combustion and finally for landfill disposal.

The Circular Economy concept covers the concepts of industrial ecology, industrial ecosystems, industrial symbiosis, cleaner production, product-service systems, eco-efficiency and others (Korhonen, Honkasalo and Seppälä, 2018).

The definition of Circular Economy also includes the re-thinking of consumption culture. The leasing and renting of products and services instead of owning, consuming and having them physically is also a pillar of CE (Korhonen, Honkasalo and Seppälä, 2018). For example, the renting of a house or flat, the renting of a product, the sharing of working space (co-working)… Its main goal is to reduce consumption.

A great example of Circular Economy or the idea of circularity itself is the model followed in the territory of El Vallès Occidental, in Catalonia. There is an initiative called "Vallès Circular", carried out by different administrations and social, environmental and economic agents, aiming to promote CE in this territory and take advantage of the development of new ways to produce and consume, in order to gain competitiveness and help the environment. This initiative is formed by companies and their associations, the town halls and research centers (two technological centers: LEITAT and EURECAT and three universities: URL, UPC and UAB) (see Figure 3.6).

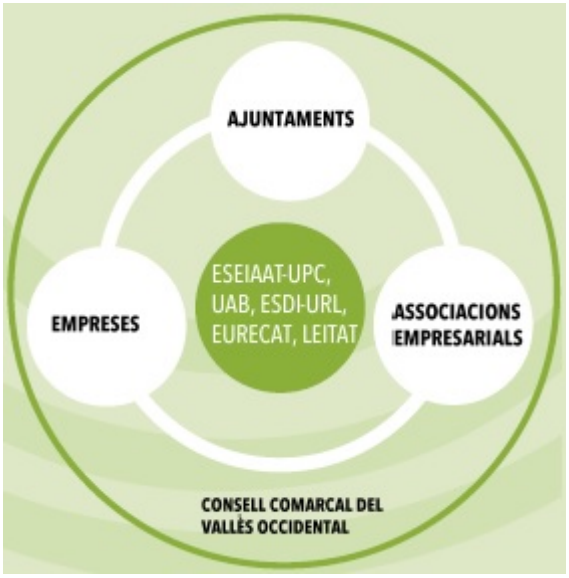


**Figure 3.6. Members of Vallès Circular (Source: http://vallescircular.com)**

Some examples of circularity carried out by this initiative are:

- The use of metal-containing waste from a company to recover the metal by dissolving this waste in acids.
- The reuse of textile waste to create new textile products.
- The reuse of packaging waste to pack other products from other companies (i.e. drums).

A good example of CE is one used after a study on packaging in a company. In this company, they used eucalyptus wood sheets in order to separate loaded pallets to prevent damaging each other during the storage. After the study, the replacement of these wood sheets for virgin PP, recycled PP and mineral filters resulted much more efficient in terms of number of uses (more than ten times higher), lower weight, use of recycled PP and thus, environmentally-friendlier. Once the number of uses reaches its top, the same company can easily recycle these plastic replacements (Puig *et al.*, 2019).

## 3.2. History of IE and CE

In this section, there is a brief summary about the history of these two concepts, in order to put more in context their origin and the development in the timeline, so that it can be more visual and, therefore, easier to compare in the fifth chapter.

The origin of both concepts is unclear, as both have the circular idea of using waste as resource. The idea of circularity was born much early, in 1848, when the first President of the Royal Society of Chemistry said that “in an ideal factory, strictly speaking, there is no waste, just products. The better a factory uses its waste, the closer it gets to being ideal and the bigger is the profit” (Murray *et al.*, 2017).

Others claim that it was in 1966, when Kenneth Boulding wrote: “Men have to find their place in a cyclical ecological system capable of continuous reproduction of material even though it cannot avoid having inputs of energy” (Murray *et al.*, 2017).

- **Origin of Industrial Ecology:** Industrial Ecology began to appear sporadically in the 1970s, but was announced in the first place at the end of the decade of the 1980s, when traditional and reactive approaches, such as “end-of-pipe” were beginning to be seen as inefficient in terms of treating industrial waste in manufacturing processes (Saavedra *et al.*, 2018).

  From this point on, the analogy between industrial and biological ecosystems was set as the core for IE (Erkman, 2002).

- **Origin of Circular Economy:** The origin of the Circular Economy concept is unclear, as there is not any evidence on it. Some authors think it might be inspired in a thesis "The limits to growth" carried out by Rachel Carson of the Club of Rome in the 1970s (Winans, Kendall and Deng, 2017). In 1989, pioneers such as Pearce and Turner stated that the traditional model of linear economy was not sustainable and, therefore, should be replaced by a circular model (Geisendorf, 2017).

  According to the literature (Murray *et al.*, 2017; Geisendorf, 2017), CE has been developed on the basis of other approaches, such as: the systems theory (stating that an economy should be analyzed in a holistic thinking approach); the second thermodynamics law (all isolated systems tend to increase their entropy over time, thus devaluating higher order of energy and material) and on industrial ecology.

Circular Economy has been developed in close relation with Industrial Ecology, but with three levels of application: single enterprise, inter-firm cluster at a supply chain level and entire cities. It is because of this close relation that they have a shared lineage with numerous characteristics in common, with much overlap.

Parallel to Industrial Ecology, born from groups of academics, other concepts with stronger focus on economics, such as Environmental Economics, Ecological Economics or Socioecological Economics were developed with the same origin. Unlike them, Circular Economy emerged and was developed from legislation, especially in China, where it was installed as its major framework to promote increased growth with decreased environmental damage (Murray *et al.*, 2017).

## 3.3. Limitations

Of course, the theory of both concepts is innovative and more advantageous than former and current models, but everything has its own drawbacks or limitations. In this section, the main limitations of Industrial Ecology and Circular Economy will be summarized.

### 3.3.1. Limitations of Industrial Ecology

Industrial Ecology used to be limited to industrial processes (Geisendorf, 2017), although in the last decades it has evolved into including economic processes (production and consumption). It also focuses more on the environmental aspect of the new strategies, rather than in their profitability.

For Graedel, Allenby and Linhard (1993), as for many researchers, there are limitations and difficulties in the concept and application of IE. Some of them are listed below:

- It may be difficult to alter a process, in order to improve its cyclic nature, as it is often difficult to raise enough capital to carry it out, unless this change has profit.
- Government regulations are often an obstacle to the change into a reuse of materials policy and are more in favor of enhanced waste flow.
- The price system may prevent Industrial Ecology from being adopted by manufacturers and producers, by not being able to include externalities in prices and costs.
- The desire of nowadays' customers for high standard of living encourages either extended-life products or early product disposal.
- Perseverant technological evolution and products' obsolescence difficult facile adoption of IE and thus contribute to an increased creation of waste.

Industrial ecosystems cannot be studied to biological systems with ideological assumptions, otherwise it will lead to false hope or disappointment, as no ideal industrial systems exist (Jensen, Basson and Leach, 2009).

### 3.3.2. Limitations of Circular Economy

As it is a rather new concept, although it is spreading fast, it is still in its inception. This means that most of the companies still do not have a structure that is compatible with its functioning and development.

One of the limitations of Circular Economy is that most of the global energy consumption (approximately 75%) is based on non-renewable sources, mostly combustion (Korhonen, Honkasalo and Seppälä, 2018). The emissions of these combustions are released in the biosphere and afterwards, they reach the ozone layer.

Therefore, even though Circular Economy is more efficient and environmentally friendly, as the main energy sources globally used are non-renewable, its approach cannot be as extended as expected.

The use of biofuels and biomaterials has an important role in CE, but the assessment of their environmental impacts still has methodological limitations, mostly regarding the method of life cycle assessment (LCA) (Korhonen, Honkasalo and Seppälä, 2018), because of the complexity of bioenergy systems and the significant changes of the market forces, relevant to LCA and policy.

The Circular Economy concept cannot work for thermodynamics, as no system is totally circular or closed; there are always energy dissipations due to the entropy law. Its application causes a decreasing phase instead of a growth-oriented one on the economic system (Winans, Kendall and Deng, 2017).

Another limitation or problem of CE is Jevons' paradox and the rebound effect, which states that the better the technology (and efficiency) in a product, the more it is consumed (Winans, Kendall and Deng, 2017). Therefore, instead of reducing the amount of energy and materials used, this causes the contrary effect, as it tends to increase the total amount of energy consumption.

# 4. Results of the survey to experts

As it has been explained in the "Methodology" section, after compiling numerous email addresses from the articles reviewed, a questionnaire was delivered to them.

In order to make the survey randomly, the various responses regarding the age, gender and location from the experts were not taken into account. They were asked only to know the generic profile of the experts in IE and CE. After carrying out a survey throughout this questionnaire to the experts on Industrial Ecology and Circular Economy, these are the results of each question, along with some comments.

Regarding the age of the 41 respondents, the relevant distribution is shown in Figure 4.1. As it can be seen, the majority of them are concentrated in the ranges 31-40 and 50+.

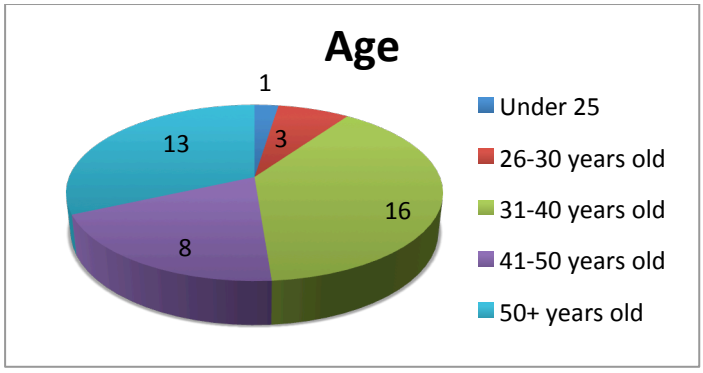


**Figure 4.1. Age of the participants**

The gender of the participants in this questionnaire is distributed as shown in Figure 4.2.

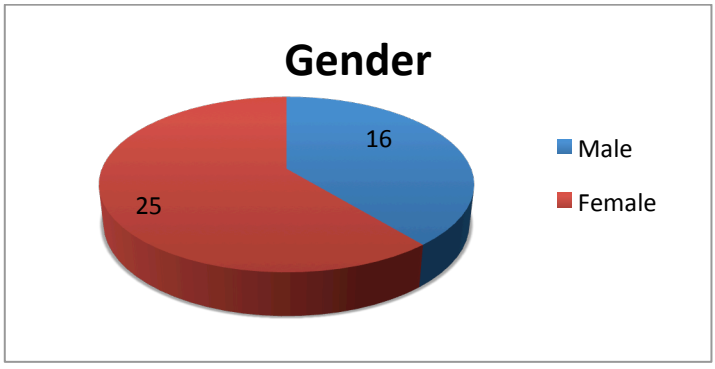


**Figure 4.2. Gender of the participants**

The majority of participants were female, as much as 60%.

Regarding their own field, the majority of participants (51,2%) chose “Environmental research” as their main field of study, and few others chose to write their main field of study, which was related to this one as well (see results in Table 4.1).

| Field of study | Nº answers | Answers (%) |
|---|---|---|
| Environmental research | 21 | 51% |
| Engineering | 6 | 15% |
| Economics | 4 | 10% |
| Business | 4 | 10% |
| Humanities | 1 | 2% |
| Circular Economy background: PhD engineering | 1 | 2% |
| Agroecology, industrial ecology, social ecology, circular economy | 1 | 2% |
| Governance sustainability & innovation | 1 | 2% |
| Environmental policy | 1 | 2% |
| Social science | 1 | 2% |

**Table 4.1. Main field of study of the participants**

As it was stated before, in order to make the questionnaire without choosing the participants' location or gender, the participants of the survey came from different countries, especially Spain. This is the chart (see Table 4.2) that summarizes the results:

| Country | Nº answers | Answers (%) |
|---|---|---|
| Spain | 18 | 44% |
| Brazil | 5 | 12% |
| Germany | 3 | 7% |
| Italy | 3 | 7% |
| Netherlands | 3 | 7% |
| Portugal | 2 | 5% |
| France | 2 | 5% |
| Columbia | 1 | 2% |
| North America | 1 | 2% |
| Peru | 1 | 2% |
| Poland | 1 | 2% |
| United Kingdom | 1 | 2% |

**Table 4.2. Country of the participants**

As regards "Place of work", as it was an optional field, there were some participants who did not fill it in (see responses in Table 4.3). It was optional because people tend to avoid being identified, especially in a professional environment. Also, there were others who simply wrote the type of place, but not from where.

| Place of work | |
|---|---|
| University | 6 |
| Santiago de Compostela University | 5 |
| Research Center | 4 |
| Cantabria University | 2 |
| Delft University of Technology | 2 |
| FC-UL | 1 |
| Federal University of Rio de Janeiro | 1 |
| Independant Researcher | 1 |
| Jagiellonial University | 1 |
| NOVA University Lisbon | 1 |
| Pontificia Universidad Católica del Perú | 1 |
| Pontificia Universidad Javeriana | 1 |
| Roma Tre University | 1 |
| Sao Paulo Federal Institute | 1 |
| UNESCO Chair in Life Cycle and Climate Change | 1 |
| Universitat Rovira i Virgili | 1 |
| Universitat Pompeu Fabra | 1 |
| University of Navarra | 1 |
| University of Sao Paulo | 1 |
| Wuppertal Institute for Climate, Environment, Energy | 1 |
| Inèdit | 1 |
| University of Zaragoza | 1 |
| School of applied research | 1 |
| Copernicus Institute of Sustainable Development | 1 |

**Table 4.3. Place of work of the participants**

The time of involvement in Industrial Ecology and Circular Economy research was checked through the question "For how long have you been involved in IE or CE research?". The answers to that question can be found in Table 4.4.

| Experience (years) | Respondents | Respondents (%) |
|---|---|---|
| Still haven't | 0 | 0% |
| 1-5 years | 11 | 27% |
| 6-10 years | 11 | 27% |
| 11-15 years | 6 | 15% |
| 16-20 years | 6 | 15% |
| 20+ years | 7 | 17% |

**Table 4.4. Time period of expertise in IE or CE research**

Over 63% of the participants were situated between 1 and 10 years of experience in Industrial Ecology or Circular Economy research, although the ranges were evenly distributed.

As for the main questions, about the differences and overlaps between Industrial Ecology and Circular Economy, the answers were the ones that follow (see Table 4.5).

| Overlaps | | |
|---|---|---|
| Type of answer | Nº of answers | Answers (%) |
| Yes | 40 | 98% |
| No | 0 | 0% |
| I'm not sure | 1 | 2% |

| Differences | | |
|---|---|---|
| Type of answer | Nº of answers | Answers (%) |
| Yes | 35 | 85% |
| No | 3 | 7% |
| I'm not sure | 3 | 7% |

**Table 4.5. Overlaps and differences between IE and CE**

The main overlaps of these two concepts, from the experts' responses of the survey are the ones summarized and listed below:

- IE has evolved to CE. Everything that IE promotes and more is included in CE. Circular Economy is a wider concept. IE is one of the core disciplines to obtain CE.
- They have the same objective: the resource optimization and the waste reduction.
- Use of renewable energy and resources and proximity to reduce transport.
- They share common principles, such as the investigation of materials cycling through both natural and built systems accounting for environmental and human health impacts associated with this systems.
- The use of materials and energy in cascade form.
- The focus on synergies between industries and other economic activities; synergies of wastes, water, energy, information, etc. between different economic agents.

- Common approach at understanding the life cycle idea and more effective usage of resources, as well as the enhancing of the durability of the products.
- CE is a model of economic development of a country and IE is a field of application of CE geared towards the industrial environment.
- Material flows approach, loop technologies and value chains. Both concepts are about closing the loop, using waste streams of one process as resource for other production processes.
- The combination of management skills to provide a more harmonized use of raw materials.
- The premise that they give value to wastes from processes and they are transformed into valuable resources for other processes, therefore the extraction of virgin resources and emissions to the environment are avoided.

The most repeated overlaps amongst the experts' responses were: the idea of circularity, as the use of one company's wastes can be turned into resources for another one, the resource optimization and the waste reduction, throughout the idea of material and energy flows and creation of loops and the use of renewable energies and reduction of environmental impact.

On the other hand, regarding the differences between both concepts, the experts' responses of the survey are the listed below:

- As a main difference, CE is a much more general and a wider concept, whilst IE is more specific.
- Industrial Ecology focuses more on the industrial and technical approach, while Circular Economy is closer to economy and politics from a strategic perspective and it focuses on behavioral and cultural aspects too. This is why CE is more publicly visible.
- CE has an intention of creating jobs (CE principles, unlike many environmental related concepts, are derived from various schools of thought).
- IE is restricted to industrial issues and, on the other hand, CE extends its concepts to all society activities.
- CE is a wider concept that also focuses on economic concepts and consumer's behavior, relationship between consumers and producers, social aspects...
- The degree of references to the biological analogy is the core in Industrial Ecology and it tends to disappear with Circular Economy.
- The territory consideration: IE is applied locally, while CE has different scales of application, including a global approach.
- IE is more focused on people's coordination and CE is about product optimization.

- IE is a robust field of study that includes many different issues, whereas CE is more of a philosophical approach. IE has a more quantitative perspective and CE is more conceptual.
- CE includes more fields than IE, for example, life cycle assessment or other environmental management tools.
- Industrial Ecology is a discipline, an academic field, which has been developed to supply methods and techniques to diminish the environmental impact, through cooperation between manufacturing systems. Circular Economy is an abstract construct that captures a trend and indicates a pathway, a policy concept, but not a discipline.
- CE tends to portray closed loops as an end, even if environmental impact in not necessarily reduced, whereas for IE the focus is this one. IE tends to take a more critical perspective towards sustainability.
- The resources involved in CE is much more significant than in IE, since the people in charge of CE management are in a higher hierarchy position.
- Industrial modeling methods that imply great uncertainties keep IE researchers from stating policy recommendations, whereas CE decision makers are not so easily prevented, as they are used to dealing with uncertain modeling.
- IE is based on a business-to-business model, whereas CE may have other types of businesses, such as business-to-consumers, consumers-to-consumers or consumers-to-business.

The most repeated difference amongst the experts' responses were that CE was a newer, but wider concept than IE, in a way that it included most of IE approaches, but also other approaches, such as political, social and economic matters. CE has a more social and people related approach, whilst IE focuses more on technical and industrial issues. IE has a local application and, on the other hand, CE has different scales of application, including a global approach.

There are multiple articles that state that CE emerged as a branch of IE, but as a concept is much wider, as it contemplates IE approaches and much more. Also, related to this previous statement, it was repeatedly said that IE was an academic field, a discipline with specific principles, whilst CE was not a discipline, but a more philosophic concept.

# 5. Comparison between Industrial Ecology and Circular Economy

As a way of comparison between the two concepts, this chapter has three different ways of doing it: regarding the definitions used from articles in chapter 3, regarding the answers of the questionnaire to experts and the use of a few other articles, which had already a comparison section between IE and CE. These three comparisons will have repeated ideas, which will mean they are the most important or visible ones.

Below are described the three different ways of comparison between the concepts of IE and CE.

## 5.1. Comparison regarding the review performed in this project

After having summarized the main ideas of the articles selected in chapter 3, defining the concepts of IE and CE, in this section, a comparison of these two concepts will be made. The following arguments are obtained as a result of the end-of-degree project literature review.

The main overlaps that can be extracted from the definitions, history and limitations of IE and CE are the following ones:

- The idea of circularity, the aim that makes materials and energy flows circulate, reducing the amount of waste created. They are both contrary to the linear model of take-make-dispose.
- The main idea or strategy can be applied in different facets of society, as both include methods relevant to business management.
- Both concepts aim to optimize the management of resources increasing interactions between stakeholders in the same geographic area (IS).
- The two concepts have a great focus on ecology (use of ecological resources, reduction of pollution, environmentally-friendly idea...).
- They both stimulate business opportunities by reducing negative environmental impacts.
- IE and CE can be defined in multiple ways and from different approaches. They do not have a single definition.

The main differences that can be extracted from the definitions, history and limitations of IE and CE of Chapter 3 are the ones listed below:

- IE is a scientific field, whilst CE is a more philosophical concept.
- IE tries to imitate natural ecosystems' functioning in industrial configurations, whilst in CE this idea tends to disappear.
- CE has a stronger focus on product reuse, remanufacturing and leasing. Also, a philosophy of using a service, rather than owning a product.

- IE has a strong focus on industry and technology. CE, on the other hand, is more focused on economy and politics.
- Unlike in CE, government regulations are often an obstacle to the implementation of an IE model. This is due to the decision makers' different position of each concept.
- The IE concept was born earlier than the CE one and it is often stated that, aside from the width of either concepts, CE emerged from a branch of IE.

## 5.2. Comparison regarding the survey to experts

As it was the author's first time comparing these two concepts, there was a part of the end-of-degree project dedicated to asking the experts on the subject for their point of view.

The comparison of this method can be found in Chapter 4, through a list of differences and overlaps between IE and CE.

## 5.3. Comparison using other articles

During the process of the literature review for chapter 3, a small amount of articles that had a comparison between IE and CE were found and kept for the comparison chapter. Therefore, they will be used for a third type of comparison in this section.

According to numerous articles on the issue, it is considered that Circular Economy is a broader discipline than Industrial Ecology. Most of all, it is due to the inclusion of economic and policy issues that CE takes into account and IE does not (Saavedra *et al.*, 2018).

Industrial Ecology can be helpful to a transition towards Circular Economy, throughout the creation of different alternatives of materials and the waste that they generate by reusing, repairing, recycling and remanufacturing (Saavedra *et al.*, 2018).

Saavedra *et al.*, 2018, state that there are several contributions of IE to CE, taking into account Ellen MacArthur Foundation, 2015's definitions and basis for CE. Some of these contributions are:

- The study of materials and energy flows and their application.
- The introduction of the principles of biological systems into industrial systems.
- The transformation from a linear flow to a circular one.
- Elimination of the dependence on finite stocks and reuse of waste generated into the system.
- The use of Industrial Symbiosis (IS).

- The use of strategies, such as the 6Rs.
- Extension of the life cycle of products.
- Use of services, rather than consuming products.
- Implementation of Eco design and cleaner production.

After a large review on the scientific literature about Industrial Ecology and Circular Economy, there has been the elaboration of Table 5.1, adapted from Geisendorf, 2017's article "The circular economy and circular economic concepts – a literature analysis and redefinition".

| Concept | Industrial Ecology | Circular Economy |
|---|---|---|
| Focus on environment | Yes | Yes |
| Focus on profitability | No | No |
| Includes social aspects | No* | Yes |
| Efficiency and waste reduction | Yes | Yes |
| Zero waste | No | Yes |
| Technological or biological substances | No | Yes |
| Business model perspective | No | Yes |
| Focus on operations | Yes | No |
| Policy | Yes | Yes |
| End of life/ disposal | Yes | Yes |

| Concept | Industrial Ecology | Circular Economy |
|---|---|---|
| Primary sector | Yes | Yes |
| Secondary sector | Yes | Yes |
| Tertiary sector | No* | Yes |
| Macro-economic perspective | No | Yes |
| Meso-economic perspective | Yes | No |
| Micro: company level | Yes | Yes |
| Micro: product level | No* | Yes |
| Raw material sourcing | No | Yes |
| Production processes | No | Yes |
| Transportation | Yes | Yes |

**Table 5.1. Aspects included in IE and CE**

After classifying the different items, the chart proved that CE is a wider concept than IE, since it involves many more items that are taken into account. Even so, it is also visible observing this table, that these two concepts have a lot of similarities.

It should be noted that there are some fields (the ones marked with an "*"), which initially were not representative taken into account in IE, but are now part of it.

## 5.4. Comments on the three comparisons

As a general comment on the three comparisons, it is visible that the one with more content is the one extracted from the experts' responses on the differences and overlaps between IE and CE questions. Even so, both other methods resulted successful in terms of having numerous differences and overlaps.

The comparison table adapted from Geisendorf (2017) used as the third method of comparison had more fields comparing IE and CE, but the scope of this project is not enough extensive to include every detail on it.

These three methods have been very useful to compare and to determine the overlaps and differences between the two concepts. There are, however, some arguments that were identified during these three comparisons, which have opposite statements. Therefore, it is important that they are cited below:

- In some articles, IE is considered to have only a local approach, while CE has different scales of approaches (inside the firm, between firms and global). In other articles, however, IE appears to have not just the local, but various approaches like the ones just described for CE.
- In some articles, it is claimed that CE is a wider concept that includes nearly every principle of IE, among many other characteristics and different approaches. However, in other articles, it is claimed that it is the contrary.
- Most articles state that, unlike CE, IE has almost no focus on political and economic issues, although there are others that state they both have.

# 6. Introduction of the board game

In this chapter, there will be a brief explanation of the different aspects of the game, as well as some examples that will help the reader understand its functioning.

## 6.1. Description of the game

Inside the game, each player represents a company and the game's purpose is to produce products after acquiring materials, but following green strategies and trading with other companies. During the course of the game, some random events that affect its development take place.

The game is played by 3 to 6 players (or more if the players are pairs or teams) and, depending on the quantity of players, there are fewer or more resources available. It is also developed by turns, and in each turn, the player has a variety of actions available: mine a material, bid it and sell it or buy it and the possibility to buy a Strategy card; otherwise, produce a product. In order to do so, every turn, the player rolled the dice to determine the materials that his/her pawn could reach on the board to mine, as well as the mining cost of the material. Otherwise, if the player already has the necessary materials to produce, he/she has to return his/her pawn to the main square to do so.

Every time a player produces a product, he/she gains 2 points, and the first one to reach 7 is the game winner. There are other ways to gain points (or lose points as well) carrying out specific strategies (the strategies will be explained afterwards). After producing a product, both the product card and the materials are placed in the Junkyard, where they can be reused and recycled afterwards by using Strategy cards. They can also be placed in the Private Warehouse of the player if he/she has followed a strategy in which this is unlocked.

## 6.2. Tokens and cards from the game

As they have already appeared, there are different cards that take action during the game:

- Material tokens: these tokens can be used to produce products (see Figure 6.1). They can be obtained once at a turn in two ways possible: by the player who mines it and, therefore, paying to the bank a given sum or when a player mines it in his/her turn, but it's bought by another player after winning the bid. After their use to produce a product, they are placed in the Junkyard or a player's Private Warehouse. At any given time, there are some of them that are available and some others may be placed upside down as reserves, which can be unlocked afterwards due to the effect of Strategy or Event cards.


Figure 6.1. Material tokens put on the board

- Product cards: these cards (see Figure 6.2) are the main source of points for the game, since each card is normally worth 2 points when produced. Each card is produced from different materials and depending on the quantity of materials, after producing it, the player earns more or less money. After the production, the cards are placed alongside the materials in the Junkyard or a player's Private Warehouse.


Figure 6.2. Examples of Product cards

- Strategy cards: they can be bought by players at the end of each turn and they have different prices and very different characteristics. For example: a Strategy card, which costs 500 and lets the player acquire the material at a mining price, without having to bid it, or another Strategy card, which costs 3000 and lets the player open the Private Warehouse to let him/her reuse the materials used to produce a previous product, as well as gaining 1 point automatically. There are also strategies that cost both money and points, but somehow let the player produce more efficiently (see Figure 6.3).

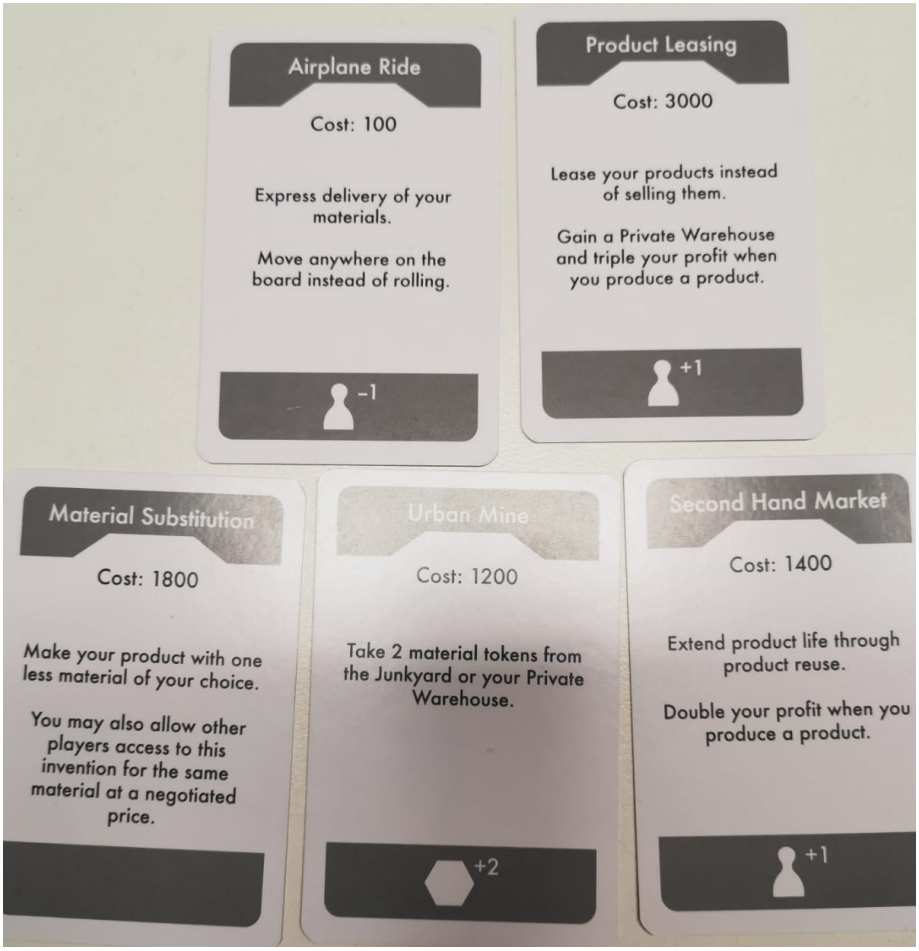


**Figure 6.3. Examples of Strategy cards**

- Event cards: these cards change every 5 minutes during the course of the game. There are 2 of them that are active at the same time, so every 5 minutes, the oldest one becomes inactive and is replaced by a new one. These Event cards have also multiple different consequences (see Figure 6.4). For example: during the time that the Event card is active, the tensions between China and the US are strong and the materials mined in China are unavailable. Another example: the price of a certain material increases by 200 units.


Figure 6.4. Examples of Event cards

## 6.3. Purposes and principles of the game

After explaining the main items that affect the course of the game, it is adequate to explain its development in a generic way.

This game is not just about having fun and trying to win like in most board games. Of course, it has also been created for academic purposes and with the goal to make people conscious about the concept of Circular Economy and the diverse aspects that relate companies, governments and countries with the environment issues.

Every single card and type of material has been thought about before choosing it for the game. In fact, every token material has a QR code in its back that can be scanned. After scanning it with a mobile phone, it redirects the player to a website where there is a description of the material, its availability, the place of extraction and its scarcity, among other curiosities.

Most of the Strategies and Event cards are related to real and current occurrences and procedures. It gives perspective of how the world works in terms of the extraction of rare elements and product manufacturing and consumption. It also lets players understand how hard it can be to negotiate with other players (and extract it as a metaphor of the trades that occur between companies and countries).

## 6.4. Evaluation of the seminar

As stated before, after carrying out the seminar as a final lecture of a 16-hour doctoral course, there was a questionnaire to fill out for the participants of the game. This questionnaire was a simple way to determine the knowledge of the students in the field of CE and their opinion on the development of the board game.

A total of 8 students answered it (their questionnaires can be found in Appendix 4) and the results of their answers can be found summarized in this section.

It should be noted that the questionnaires were developed in Italian, as most of the students were from Italy and, therefore, they are more fluent and more able to communicate in their mother tongue.

The questionnaire followed a structure of questions organized in a way that the first ones were easier and more centered into the development of the seminar and those after had a more subject-centered point of view. The more close to the end of the questionnaire, the more they made the participant focus. This structure was inspired by Harrison, (2007), same as the questionnaire to experts about IE and CE.

The first question was "Have you already used a board game or something similar as didactic assistance?" and "If so, which one(s)?" (see results in Table 6.1).

| Type of answer | Nº of answers | Answers (%) |
|---|---|---|
| Yes | 1 | 13% |
| No | 7 | 88% |

**Table 6.1. Didactic assistance with games**

The next question had the purpose of knowing whether the participants had knowledge on the concepts of Industrial Ecology and Circular Economy on a scale from level 1 to 5 (1 being none and 5 being high). As they were students with various backgrounds attending a doctoral course on Industrial Ecology, the results were the ones summarized in the following table (see Table 6.2).

| Level | Nº of answers | Answers (%) |
|---|---|---|
| 1 | 1 | 13% |
| 2 | 3 | 38% |
| 3 | 1 | 13% |
| 4 | 3 | 38% |
| 5 | 0 | 0% |

**Table 6.2. Knowledge in IE and CE**

The average knowledge of the students on these fields is 2,75/5.

As a curiosity question, the participants were asked if they already knew about the existence of this game or a similar one about IE or CE (see Table 6.3). Most of them did not know about it.

| Type of answer | Nº of answers | Answers (%) |
|---|---|---|
| Yes | 2 | 25% |
| No | 6 | 75% |

**Table 6.3. Knowledge about the existence of In The Loop or any other IE or CE game**

Afterwards, as a more subjective question to the participants, they were asked if they had enjoyed the game and which was their favorite feature or moment (see Table 6.4). The answers followed also a scale from 1 to 5, which will be used in further questions.

| Level | Nº of answers | Answers (%) |
|---|---|---|
| 1 | 0 | 0% |
| 2 | 0 | 0% |
| 3 | 0 | 0% |
| 4 | 3 | 38% |
| 5 | 5 | 63% |

**Table 6.4. Enjoyment on the board game**

As it can be seen, the results were particularly positive, as everyone enjoyed the game much. As for their favorite part or feature of the game, there were, of course, different replies:

The things that the participants enjoyed the most were the moment of choosing a strategy to follow during the course of the game, the auctions carried out each turn after mining a material, the production of the products and the ability of the event cards to turn players' strategies upside down. This last thing made clear that commodity prices are set in an arbitrary way.

The next question was a bit more demanding as its aim was to test the participants whether they caught the main idea or concept of the game. The answers had a variety of concepts: for some of them, the main idea was the management of economy during the process of production; for others, the importance of historical events in terms of their direct effect on production. For some others, the importance to choose wisely a strategy to follow and being able to adapt at all times, since there are no strategies that have a solution in every field.

Then, they were asked if they learned something from the game and, in this question, every participant approved, as they all learned at least one thing from it. Regarding the specifications of the things they learned, they were diverse, as their degree of knowledge on the fields, as commented before, was variable. Below are some examples on the lessons learned.

The most repeated concept learned among the participants' responses was the amount of rare materials and the country where they were extracted (mostly in China). Also, the importance of managing the numerous aspects involving production and better knowledge on the steps to follow in order to carry out a closer approach to CE in a company.

Afterwards, they were asked for the recognition of different elements of IE or CE. As a Yes/No question, these were the answers given (see Table 6.5).

| Type of answer | Nº of answers | Answers (%) |
|---|---|---|
| Yes | 4 | 50% |
| No | 4 | 50% |

**Table 6.5. Recognition of IE or CE strategies in-game**

As for the justification of their answer, 3 of the 4 participants who did not recognize any strategy of IE or CE did not have knowledge of the fields and the other one already knew all the strategies detected.

Regarding the other 4 participants, some of the strategies they were capable to recognize were:

- The protection of workers in the mining industry
- Recycling and reuse of products
- Sustainable production methods
- The sale of services, rather than products
- Eco design and the production of green products

The next questions asked the participants to what extent their viewpoint in some subjects had changed in some way after playing "In The Loop". The first subject was the reusing and recycling of materials. The answers were the following (see Table 6.6).

| Level | Nº of answers | Answers (%) |
|---|---|---|
| 1 | 1 | 13% |
| 2 | 2 | 25% |
| 3 | 4 | 50% |
| 4 | 1 | 13% |
| 5 | 0 | 0% |

**Table 6.6. Reusing/recycling change of viewpoint**

The main reasons for their answers were that they were already aware of reusing and recycling strategies or they did not think the game had a strong focus in it.

The other subject that they were asked to what extent their viewpoint had changed after playing the board game was the commerce and exchange of products and materials between companies and, to another scale, between countries. Their answers were the following (see Table 6.7).

| Level | Nº of answers | Answers (%) |
|---|---|---|
| 1 | 1 | 13% |
| 2 | 0 | 0% |
| 3 | 1 | 13% |
| 4 | 6 | 75% |
| 5 | 0 | 0% |

**Table 6.7. Commerce change of viewpoint**

The reason behind the 75% answered with a 4 out of 5 was the fact that it was very visible that, when a company (a player) needed a material in order to produce or realized that another company needed it in order to advance in the game, they increased their price to have more benefit on their own or even refused to sell it at any cost. This was one of the subjects that the game was best suited in reproducing the world's reality.

The following question was a bit more complicated to answer, since it required a relative knowledge on the subject. The participants were asked if they thought there were approaches of IE or CE missing in the development of the game (see results in Table 6.8).

| Type of answer | Nº of answers | Answers (%) |
|---|---|---|
| Yes | 3 | 38% |
| No | 5 | 63% |

**Table 6.8. Lacks on IE or CE aspects**

As for the three people who answered that they thought there were missing content, the lacking aspects and the suggestions for improvements of the game were various.

The cycle of production following a logical path of sustainability was lacking content on aspects of IE or CE. Although, for the next question "Do you have any suggestion in order to improve the game's functioning?" there were interesting responses:

- Addition of aspects related to regulation on environment for the events in play.
- Addition of IE related concepts with importance, such as IS.
- Add more information and specifications on Product and Strategy cards, which could be of help to identify and comprehend the CE principles they were based in.

The participants were thereafter asked if they thought the learning scope of the game was well applied. The answers were quite positive, as the following table shows (see Table 6.9).

| Level | Nº of answers | Answers (%) |
|---|---|---|
| 1 | 0 | 0% |
| 2 | 0 | 0% |
| 3 | 2 | 25% |
| 4 | 2 | 25% |
| 5 | 4 | 50% |

**Table 6.9. Application of the learning scope to the game**

The comments on this question were that it was a great way of teaching and having fun while learning the complexities and different aspects that CE presents from a company perspective, even though the main opinion also stated that the didactic approach could be more elaborated.

To conclude the questionnaire, as final questions, the participants were asked if they thought that social interaction through games was more efficient than the "traditional" didactic approach and then, particularly in this field (see answers in Table 6.10).

| Level | Nº of answers | Answers (%) |
|---|---|---|
| 1 | 0 | 0% |
| 2 | 0 | 0% |
| 3 | 2 | 25% |
| 4 | 1 | 13% |
| 5 | 5 | 63% |

**Table 6.10. Efficiency of games vs. traditional way of teaching**

The results of this table (see Table 6.11) prove that these types of social interaction are a good way (even better than the traditional way) to teach students a good deal of concepts and subjects.

| Level | Nº of answers | Answers (%) |
|---|---|---|
| 1 | 0 | 0% |
| 2 | 0 | 0% |
| 3 | 1 | 13% |
| 4 | 3 | 38% |
| 5 | 4 | 50% |

**Table 6.11. Efficiency in this particular field (IE and CE)**

More or less the same results were extracted from the question in this specific field (IE and CE).

# 7. Conclusions

In this project, a systematic literature review on published articles of IE and CE has been conducted. This review has been developed following a rigorous method and after checking-reading 19 papers on IE and 24 on CE, an explanation on what are these concepts and their history and limitations has been built. This information has resulted very useful in order to compare both subjects.

While analyzing and comparing the definitions of IE and CE, it has been noted that they both have a lot of aspects in common, but they also have numerous differences in their approaches.

Some of the main overlaps obtained after the review are: the fact that both concepts have the idea of circularity and, therefore, are contrary to the traditional linear model of take-make-dispose; both concepts aim to optimize the resources and reduce the amount of generated waste and they are both focused on ecology, avoiding pollution and using environmentally-friendly resources and materials.

On the other hand, some of the main differences are: IE is a scientific field and CE is a more philosophical concept; IE is more focused on industry and technology, while CE has a more socio-economic and political approach and that the IE concept was born earlier than the CE concept, which emerged from an IE branch.

It has been identified that both concepts have a similar origin, around the idea of finite resources and the necessity for circularity. Nevertheless, the moment when the CE approach emerged remains unclear.

There have been also found some limitations of both approaches, being some of the most notorious the ones stated below:

- For Industrial Ecology, it may be difficult to alter processes, as it is often difficult to raise enough capital to carry it out, unless this change has immediate profit.
- Perseverant technological evolution and products' obsolescence make the adoption of both IE and CE difficult, since they contribute to an increased creation of waste.
- Most of the global energy consumption (around 75%) is based on non-renewable sources. It is therefore difficult to implement some CE principles, such as adopting renewable sources as energy consumption, since it would have to change at a huge scale the way of energy consumption.
- Jevons' paradox and the rebound effect state that the better the technology and efficiency of a product, the more it is consumed. This causes an increase of the amount of energy consumption, instead of reducing it.

In order to complete this research, a questionnaire was sent to 76 experts on IE and CE, obtaining 41 answers, carefully revised and summarized afterwards. Aside from asking general questions on the age, gender, studies, country, place of work and experience on the subjects, the questionnaire mainly asked if the respondent thought there were overlaps and differences between IE and CE. The results of those questionnaires added several overlaps and differences to the ones encountered throughout the previous literature review.

The most agreed overlaps that were not extracted from the literature review, but drawn out from the questionnaires responses were: they both adopt the concept of Industrial Symbiosis (IS), which, to summarize, means that a company's wastes can be used as resources for another company; and they both focus on the durability of the products, also with the aim of optimizing resources and reducing the amount of waste.

The most agreed new differences added from the questionnaires' responses were: CE is a wider concept than IE, since it includes all IE principles, plus many others, such as economic approaches, relationship between producer and consumer, etc.; and that industrial modeling methods with uncertainties keep IE researchers from stating policy recommendations, whilst CE decision makers are not so easily prevented, as they are used to dealing with uncertain modeling.

In addition to the main objective, the comparison between IE and CE, this project had another part, in which a CE board game was used in a session with doctorate students. The goal of this part was to acknowledge if introducing this game as a didactic method was profitable for the students and had success on the transmission of knowledge to them.

The results obtained on this test were positive; since the overall opinion was that it was a great form to escape the sometimes-monotonous way of learning, while enjoying. Not only was it fun, but it also achieved the main goal of a lecture, as all participants agreed that they had learned during the development of the game.

# Acknowledgements

I would like to note a special gratitude to my end-of-degree project supervisor from Università degli studi Gabriele D'Annunzio (UdA), Pescara (Italy), professor Andrea Raggi, for his support from the first day and his assistance, not only for the project, but also in situations and complications during the author's Erasmus period abroad.

In addition, I would also like to express his gratitude to the supervisor from Universitat Politècnica de Catalunya (UPC), Jordi Fortuny, for his guidance in this project, even being far away from each other.

Also, the help of professor Ioannis Arzoumanidis, professor Alberto Simboli, professor Raffaella Taddeo and the group of professors of UdA with whom the tests previous to the seminar were carried out, as well as the group of doctorate students who were present in the session.

It is important to mention the gratitude to the experts of IE and CE, who spent a portion of their time in order to help the author enormously in the completion of this project.

Last, but not least, my family, for the patience and the emotional support during the development of this end-of-degree project and the 4 years of the degree.

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# Appendices

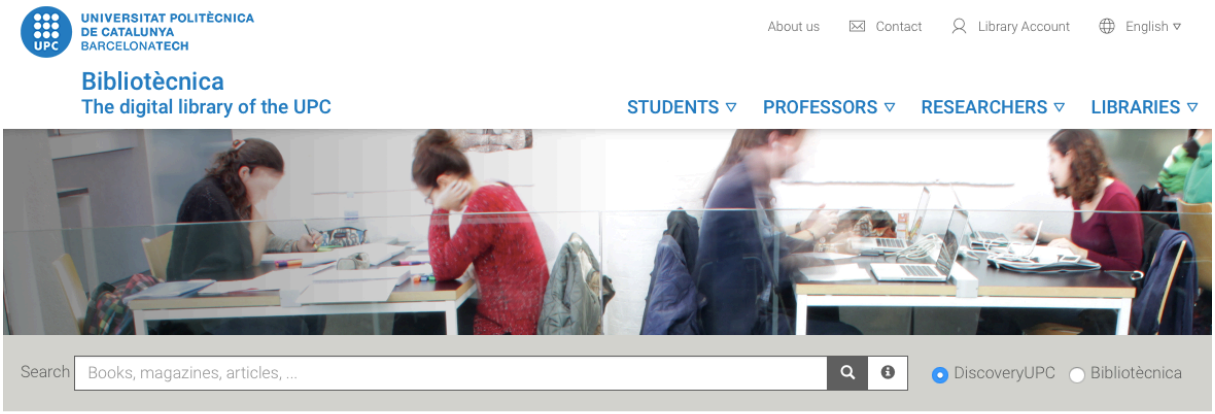
List of appendices:

# Appendix 1. Methodology of the databases' search

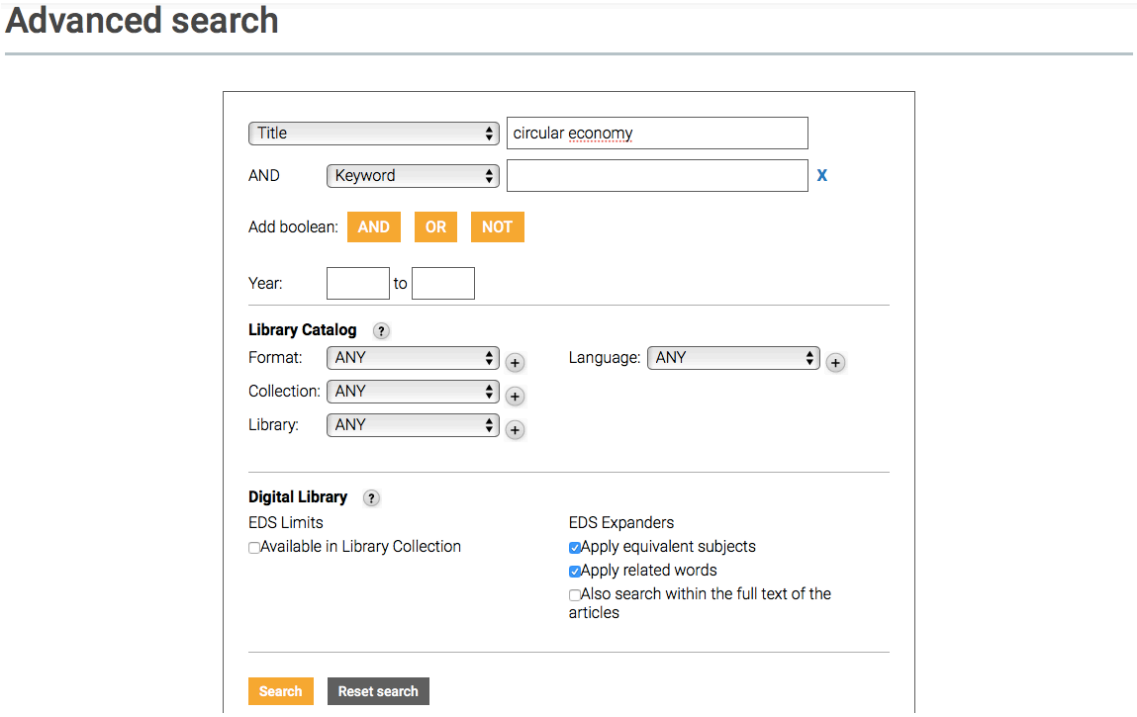
The content of this appendix, as it was defined previously, is the more visual way to show the methodology of the searches through the databases of the three universities. These are the steps followed by each of them:

1. UPC database

After accessing with the username and password of the student and clicking the digital library site of the web, this was the page where the author could start searching.




The usual search was not sufficiently concrete, so the type of search conducted was the advanced search.



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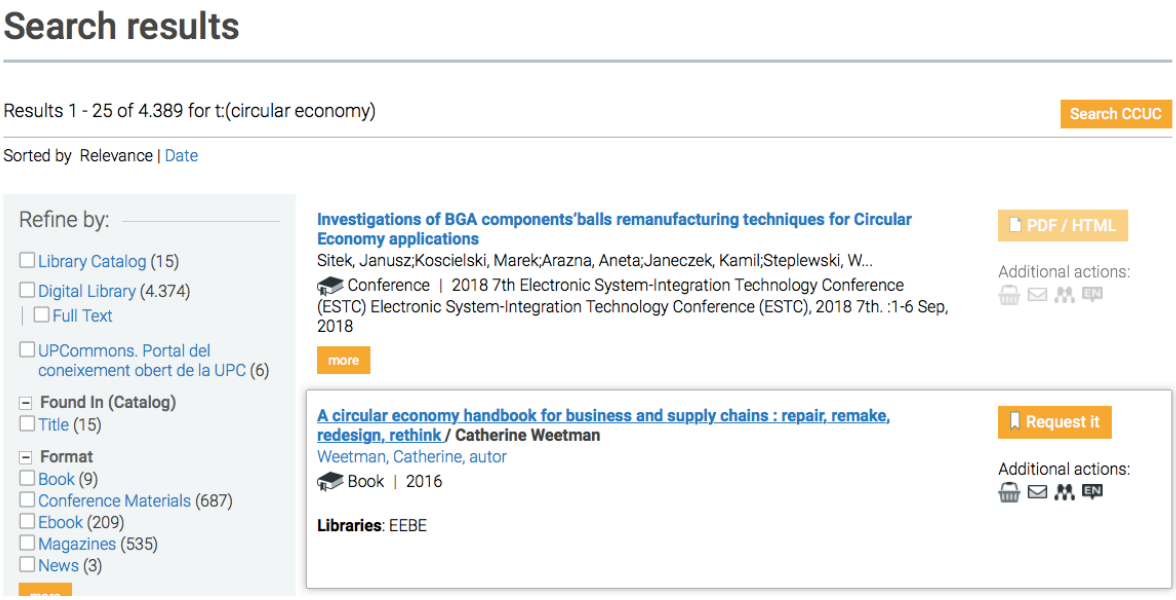
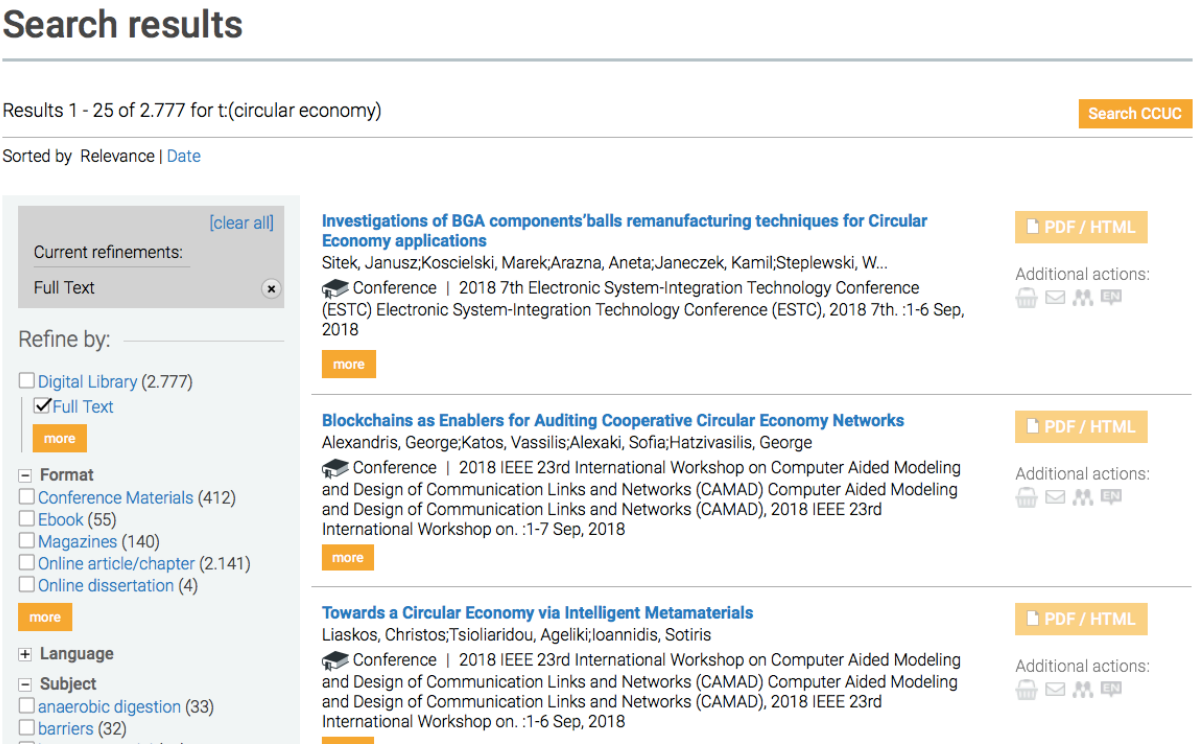
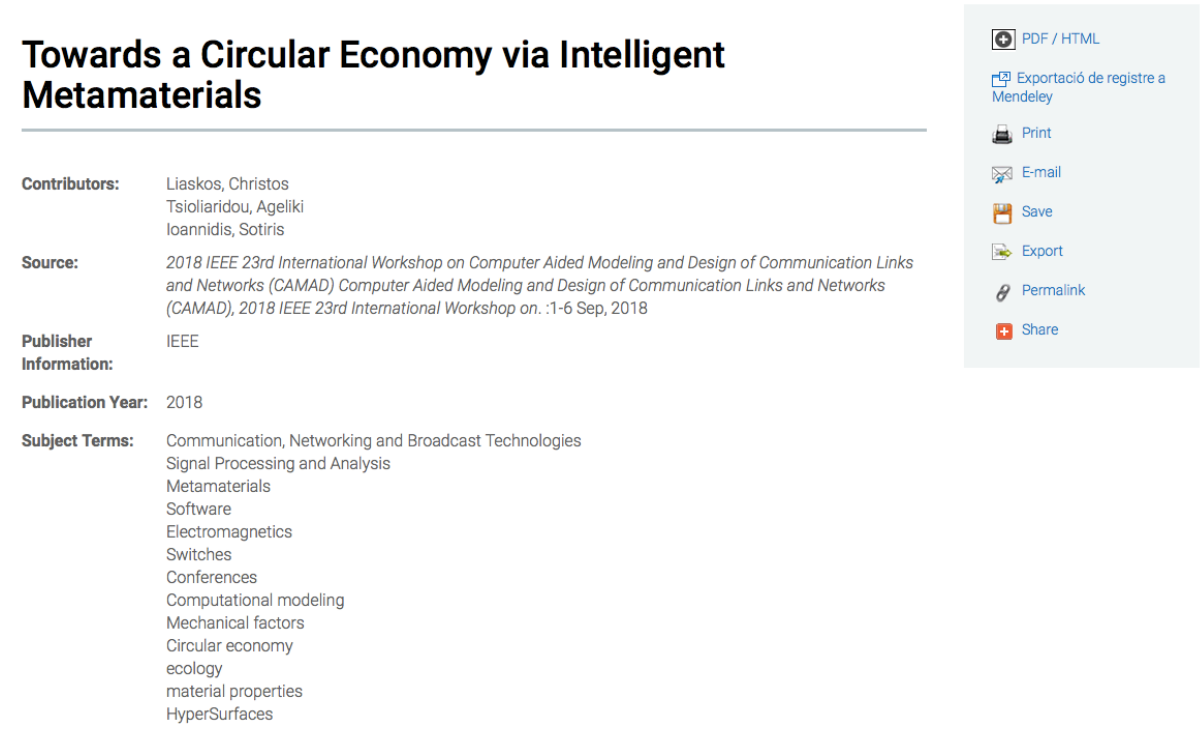



As it can be seen in the next image, after selecting these concepts, the search results were diminished.




In this example, the document clicked was "Towards a Circular Economy via Intelligent Metamaterials", and the information that appears after clicking is the following.



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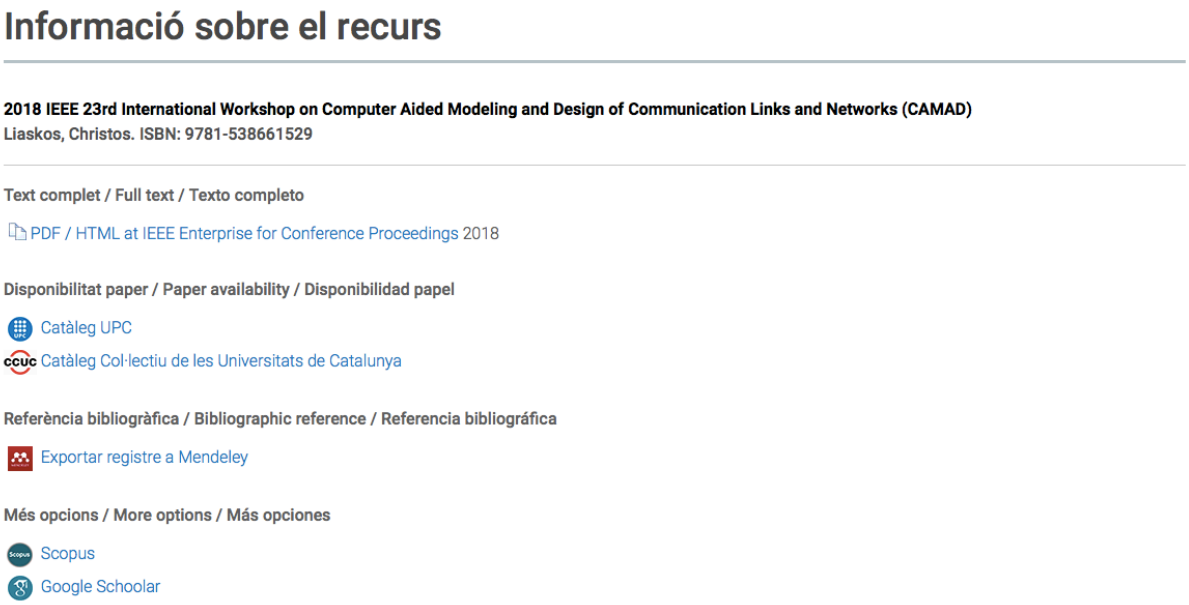

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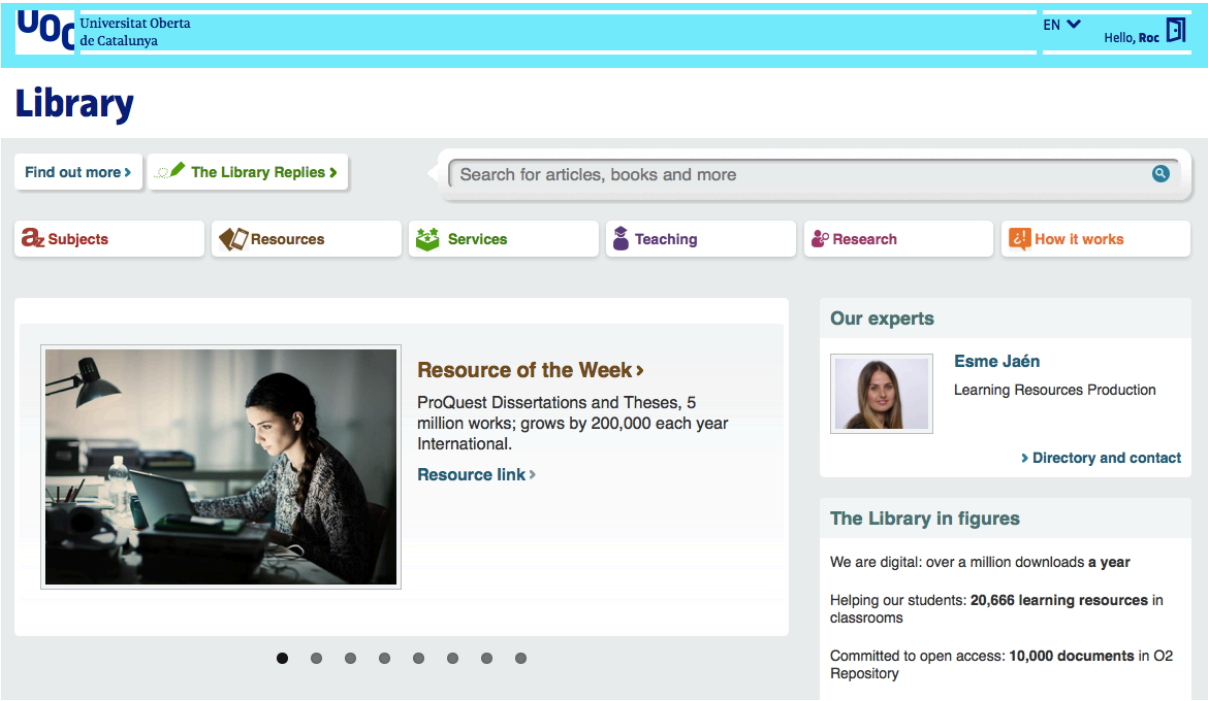
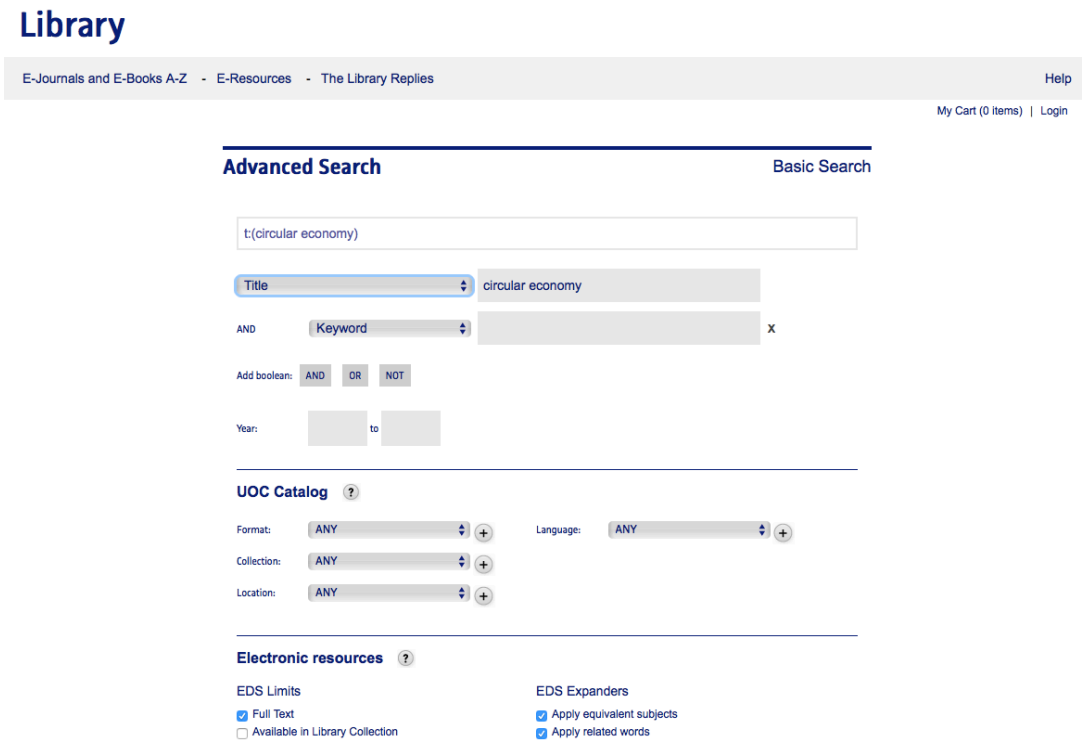
Although it has been mentioned before that, in the end, the only database used has been the UPC one, before deciding the way of development for the research, the other two databases (UOC and UdA) were also used. Therefore, here's also a brief explanation of both of them on how they were used.

2. UOC database

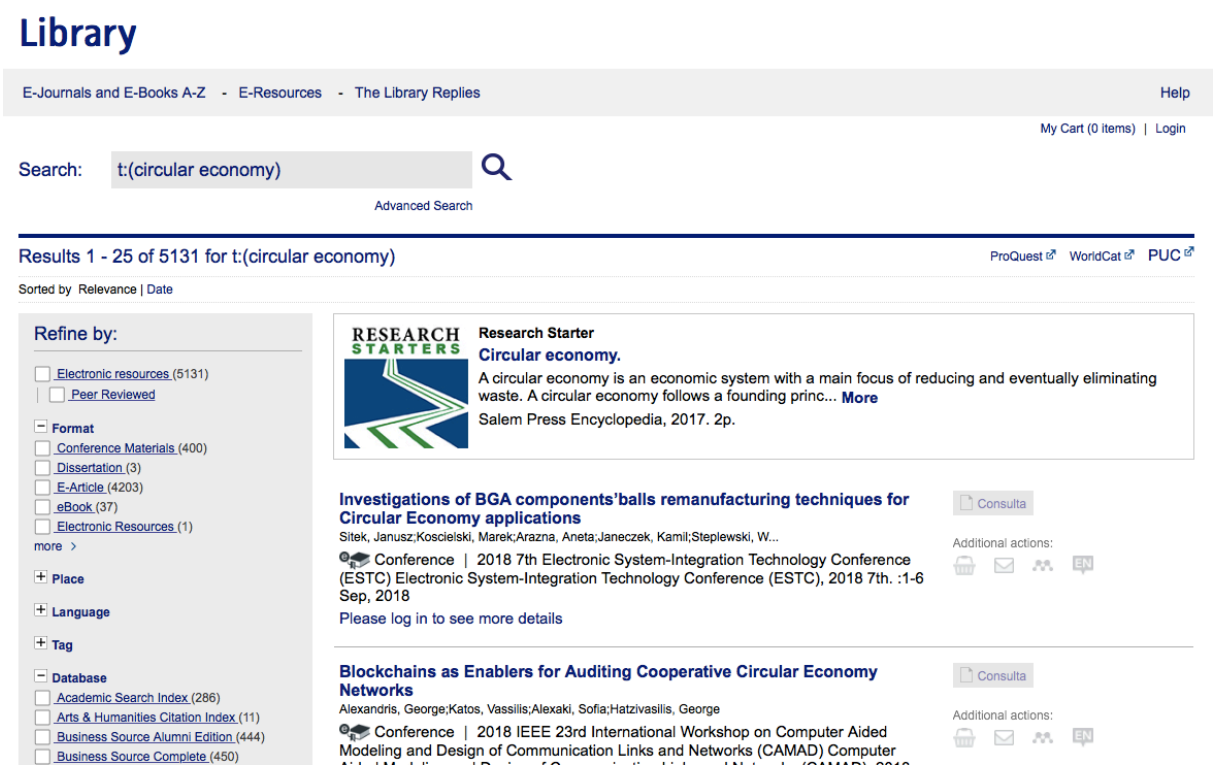
Same as the UPC database, after accessing with the username and password of the student and clicking the digital library site of the web, this was the page where the author could start searching.




As well as with the UPC database, the usual search was not sufficiently concrete, so the type of search conducted was the advanced search.




In this database, the results were not as significant as in the UPC database, so the parameters on the gray box were not as much modified as in the UPC one.

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Detailed Record

Consulta

**Circular economy in the manufacturing sector: benefits, opportunities and barriers**

**Authors:** Vikas Kumar, author
Ihsan Sezersan, author
Jose Arturo Garza-Reyes, author
Ernesto D.R.S. Gonzalez, author
Moh'd Anwer AL-Shboul, author

**Source:** Management Decision, 2019, Vol. 57, Issue 4, pp. 1067-1086.

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**Publication Year:** 2019

**Subject Terms:** research-article
Research paper
cat-MSOP
Management science & operations
cat-MSO
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Barriers
Opportunities
Circular economy

**Description:** Purpose In recent years, circular economy (CE) has come to prominence as an alternative to the classic approach of "make-use-dispose". How companies can exploit the opportunities of CE to position themselves better are not well articulated in the literature. The purpose of this paper, therefore, is to identify the barriers and opportunities of CE in the manufacturing sector through a socio-political, economic, legal and environmental perspective. Design/methodology/approach The study adopts a positivist approach, which is

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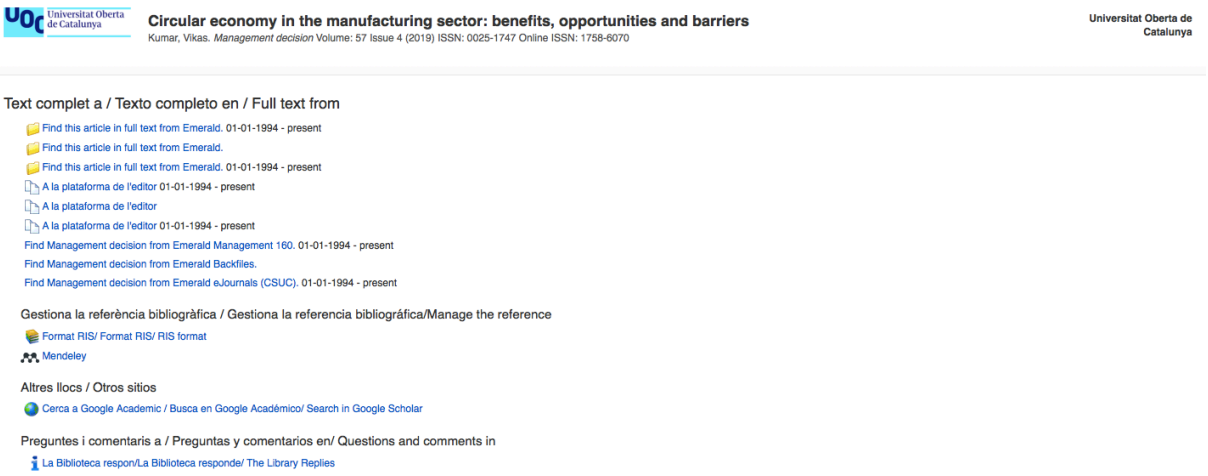

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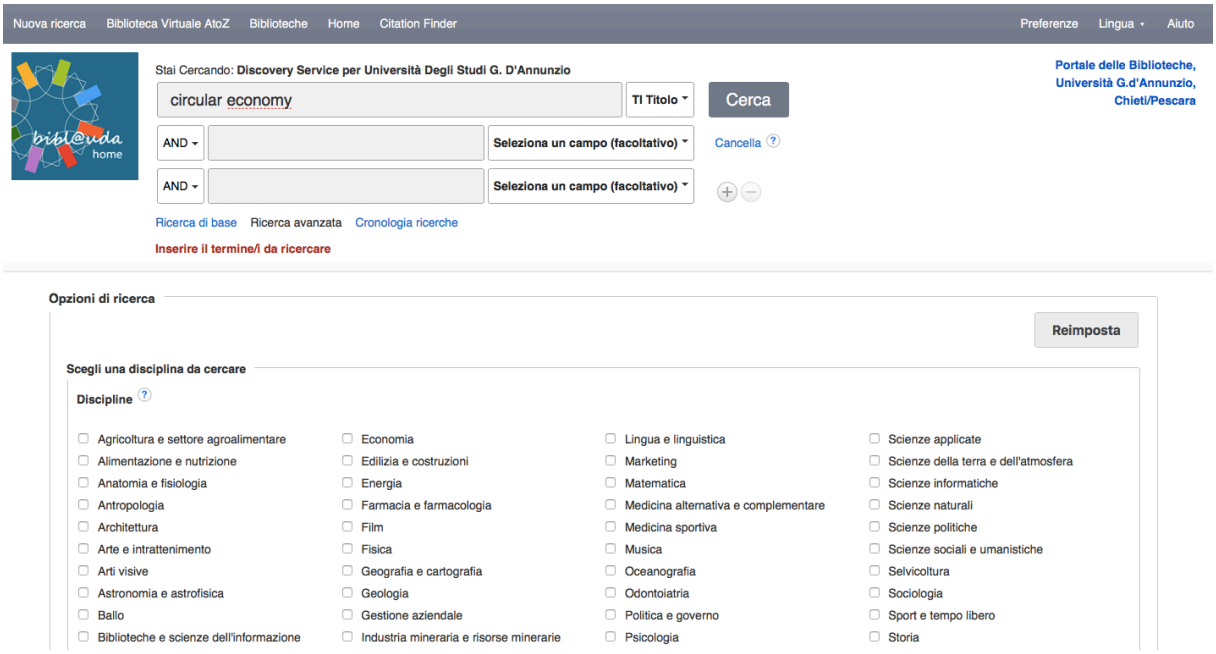
After clicking one of these folder links, the original page in which the article was published was accessed in a new Internet window.

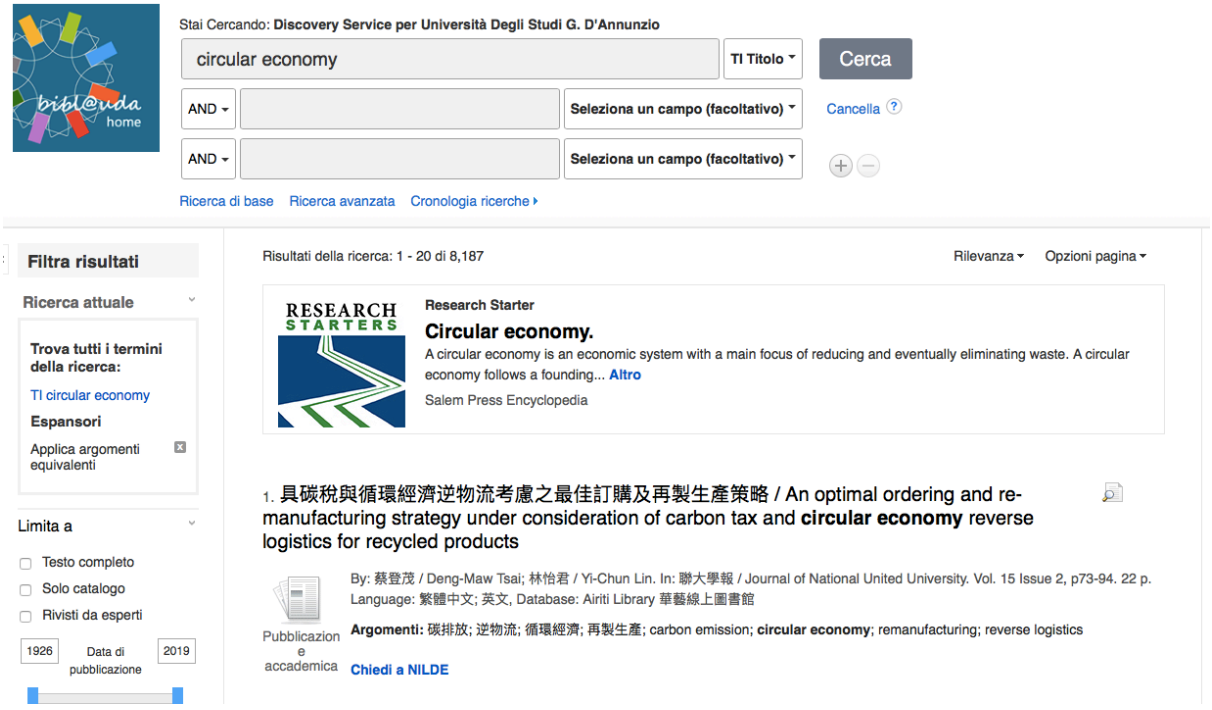
3. UdA database

Same as both other databases, after accessing with the username and password of the student and clicking the digital library site of the web, this was the page where the author could start searching.

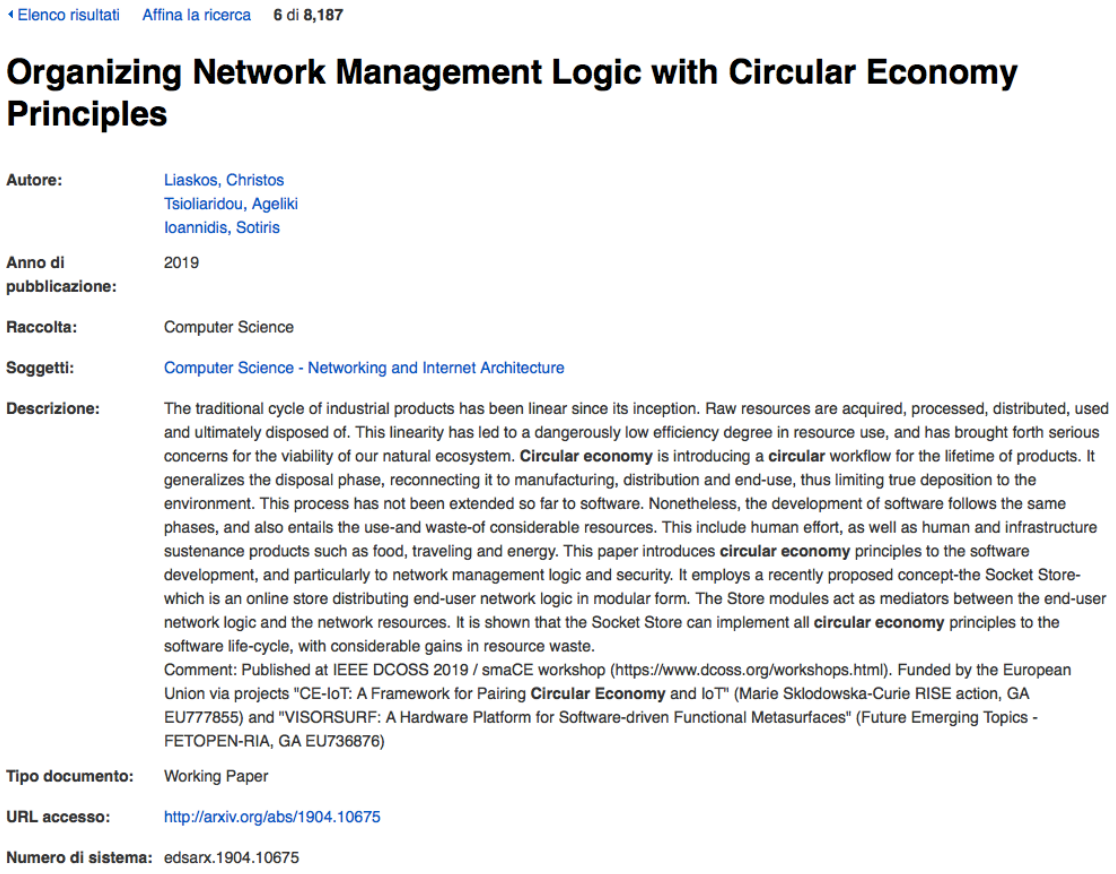

After this screen, the "Ricerca avanzata" button was the "Advanced search" that was also clicked for the other databases, in order to search in a more specific way. It can be seen in the next figure that the keywords can be found in the title or other options, as well as to include other words by using the "AND" button or the "OR" one.




After clicking "Cerca", these are the results that could be found and, as it can be seen, they can be filtered or limited by the parameters "Full text" (Testo completo), "Revised by experts" (Rivisto da esperti), the date of publication…




After selecting the articles, a page similar to the next one appears, with the title, authors, year of publication and description, among others. There is also the URL access from where it can be found and downloaded on the bottom.



## Appendix 2. Emails sent to experts for the survey

"Dear sir or madam,

My name is Roc Fullana and I am writing to you, as an expert of Industrial Ecology and/or Circular Economy. Alongside with my supervisor, professor Andrea Raggi, I am conducting my end-of-degree project regarding Industrial Ecology and Circular Economy.

The main purpose of this thesis is to determine whether the concepts above are similar, if Circular Economy is nothing but an evolution of the term Industrial Ecology or they do not have anything in common. In order to complement my thesis, I have developed a survey that I have sent exclusively to experts on the subject.

Therefore, you are kindly asked to take part in this survey. The survey is done through Google Forms and it is fast to fill. You can find the link below:

https://forms.gle/V5xRFsfeEF8rfhSdA

Thank you for your cooperation.

Kind regards.

Roc Fullana "

Afterwards, as there hadn't been numerous responses, a new email was sent. The content of the new email was a reminder of the survey, as well as a gratitude message for those who had already answered it. As mentioned, it was sent to the same group of experts on July 8$^{th}$, 2019. The email sent was the following:

"Dear sir or madam,

A few weeks ago I sent you an email with a survey on Industrial Ecology and Circular Economy, which will be used to analyze the data and help me complement my end-of-degree thesis.

I now resend the link of the survey, so that if you did not see it, forgot to answer it or did not have time at the moment, maybe you are able now. If you already answered to the survey, I am grateful and, of course, you do not have to answer it again.

https://forms.gle/2XVoiC4VQRFjUv7b7

Below there is the first mail I sent, with my information and the purpose of the survey, from the 2nd of June 2019."

As a last reminder for the experts to answer the questionnaire, another reminder was sent on August 20th, and after a week, on August 26th, the responses were blocked with a final number of 41. This last email reminder is the one that follows:

"Dear sir or madam,

As a reminder, please find attached the link of the survey on Industrial Ecology and Circular Economy for my end-of-degree thesis. It will only take 5 minutes of your time and will be really helpful for me.

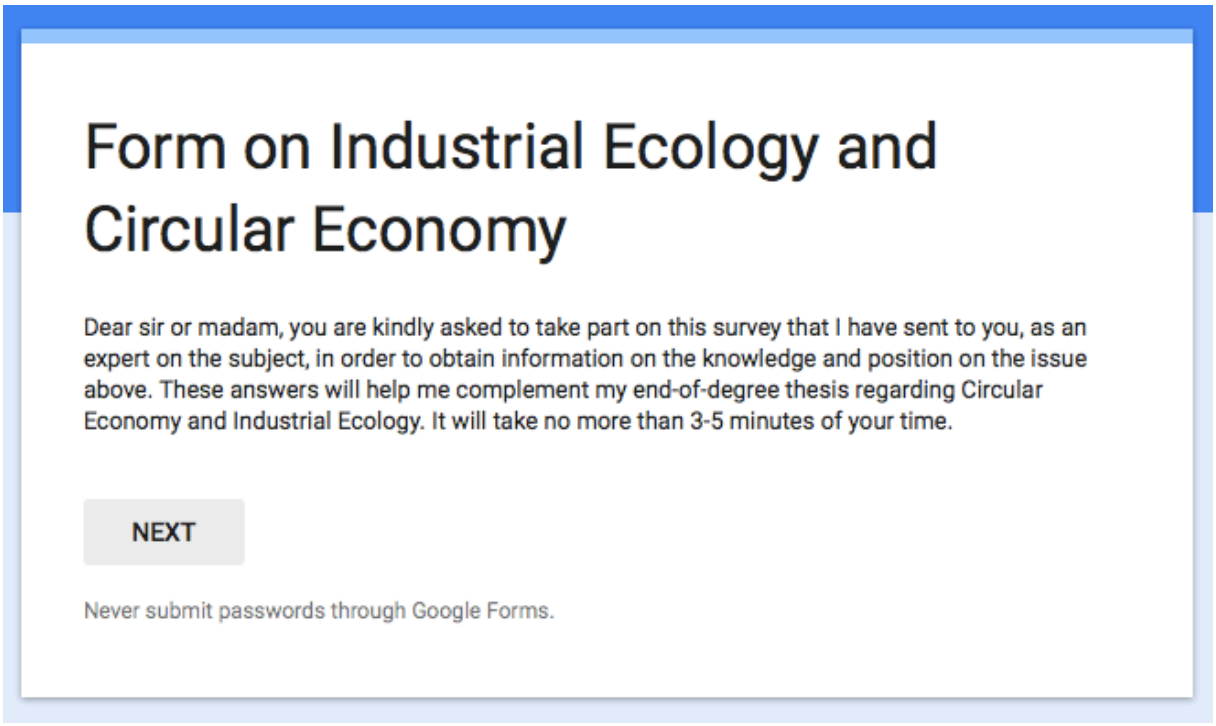
https://forms.gle/2XVoiC4VQRFjUv7b7

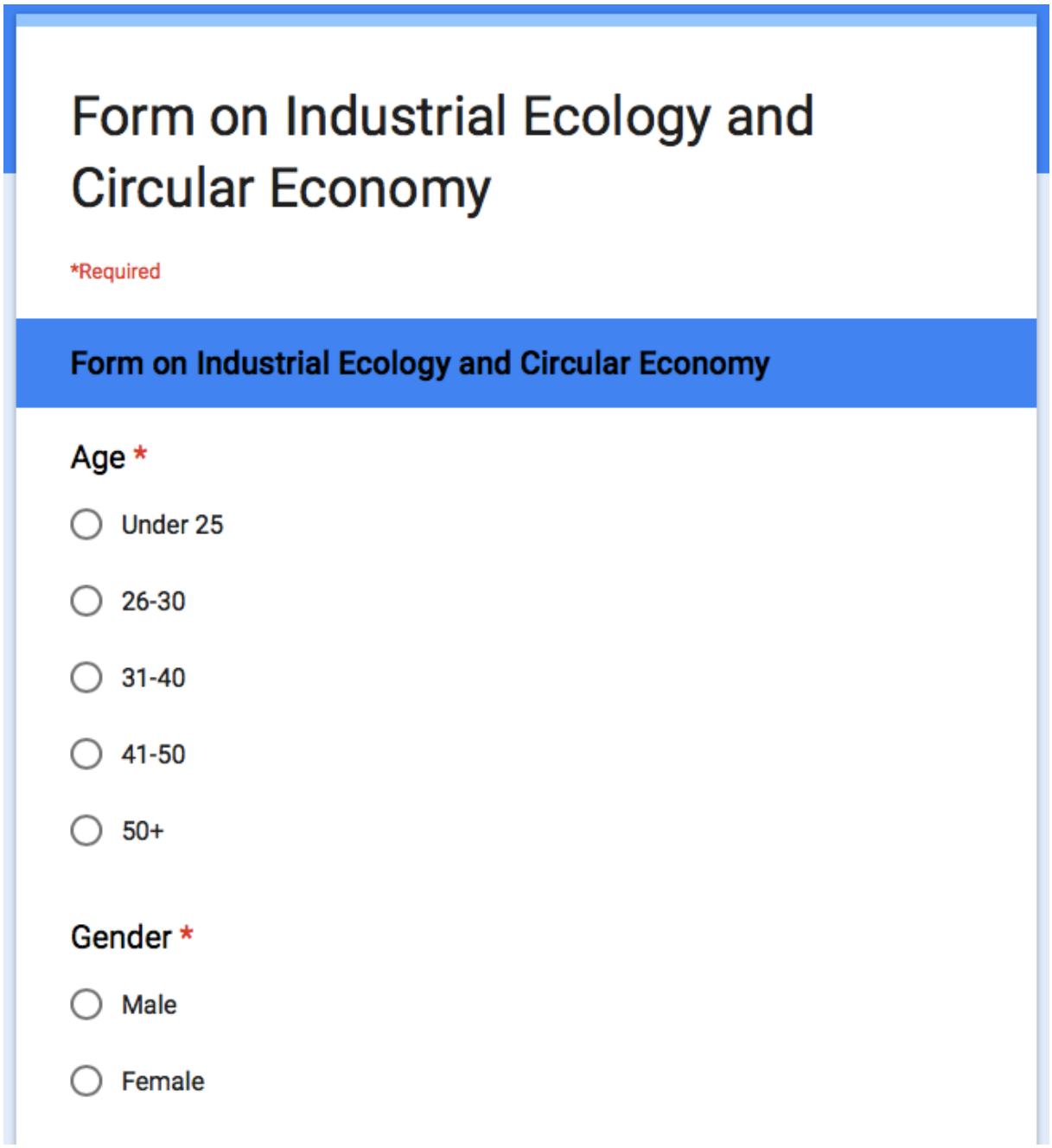
Thank you so much in advance.

Roc Fullana"

# Appendix 3. Questionnaire from experts on Circular Economy and Industrial Ecology

The content of this annex are the screenshots of the questionnaire answered by the experts on Circular Economy and Industrial Ecology. As it was defined before, the contact with these experts has been through their emails, extracted from various articles reviewed.





# Form on Industrial Ecology and Circular Economy

*Required

## Form on Industrial Ecology and Circular Economy

Age *

- Under 25
- 26-30
- 31-40
- 41-50
- 50+

Gender *

- Male
- Female

What is your main field of study? *

- ○ Economics
- ○ Environmental research
- ○ Engineering
- ○ Business
- ○ Humanities
- ○ Other: _____

Country *

Your answer

Place of work (university, research center...)
Example: University of Cambridge

Your answer

For how long have you been involved in Circular Economy or Industrial Ecology research? *

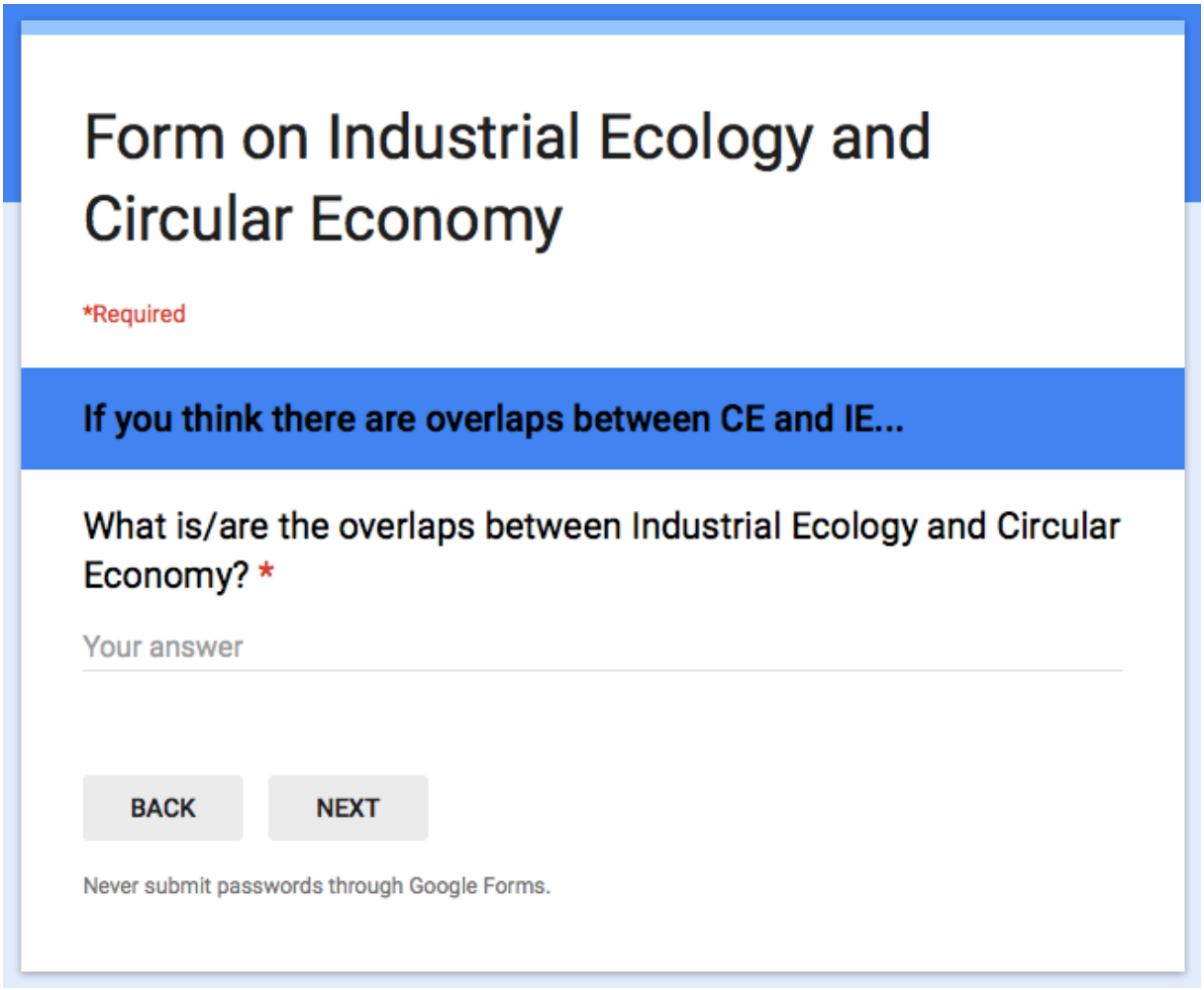
- ○ I still haven't been involved in CE or IE research
- ○ 1-5 years
- ○ 6-10 years
- ○ 11-15 years
- ○ 16-20 years
- ○ 20+ years

Do you think there are any overlaps between CE and IE? *

- ○ Yes
- ○ No
- ○ I'm not sure

BACK NEXT

Never submit passwords through Google Forms.



Form on Industrial Ecology and Circular Economy

*Required

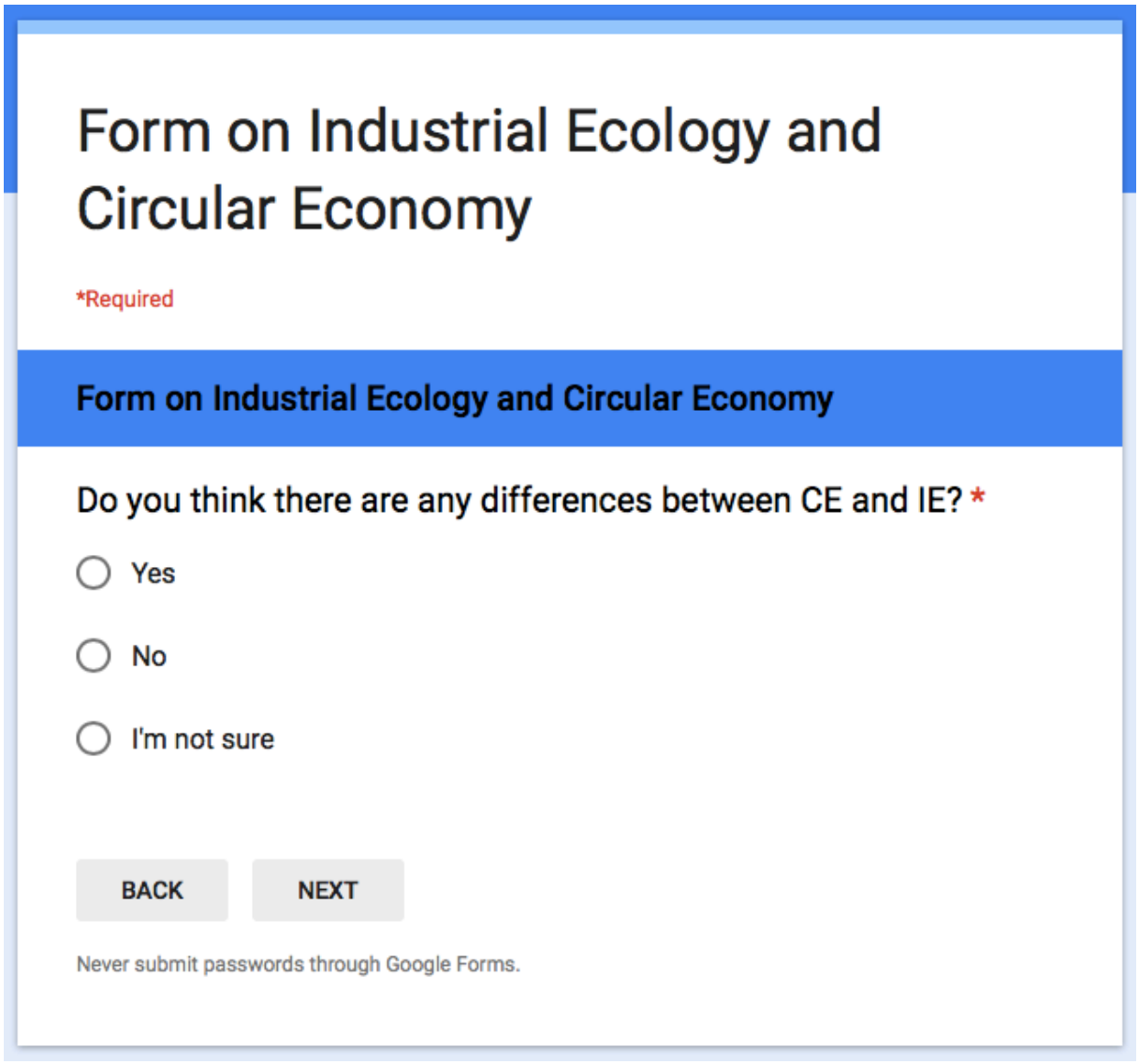
If you think there are overlaps between CE and IE...

What is/are the overlaps between Industrial Ecology and Circular Economy? *

Your answer

BACK NEXT

Never submit passwords through Google Forms.



Form on Industrial Ecology and Circular Economy

*Required

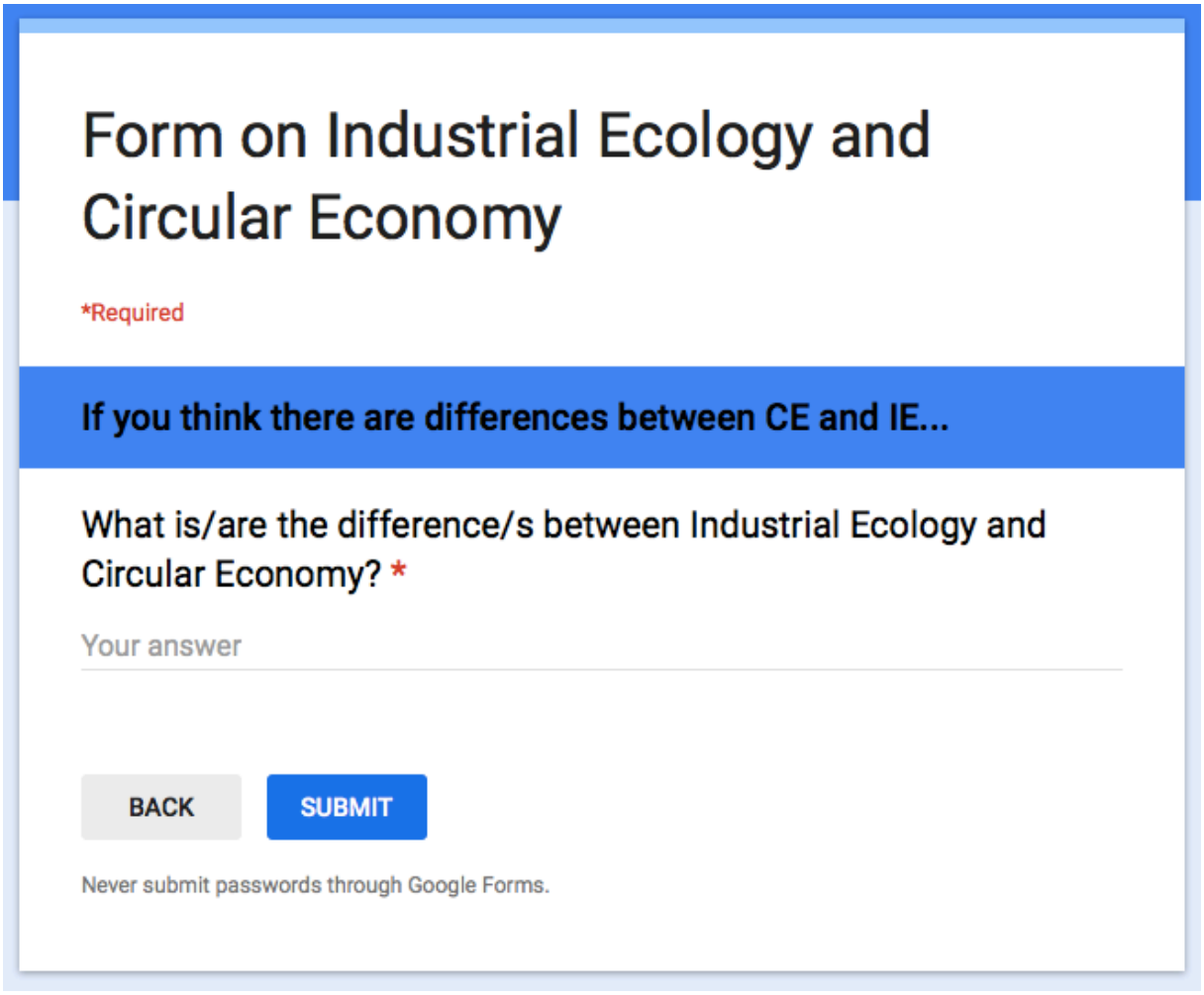
Form on Industrial Ecology and Circular Economy

Do you think there are any differences between CE and IE? *

- Yes
- No
- I'm not sure

BACK NEXT

Never submit passwords through Google Forms.



Form on Industrial Ecology and Circular Economy

*Required

If you think there are differences between CE and IE...

What is/are the difference/s between Industrial Ecology and Circular Economy? *

Your answer

BACK SUBMIT

Never submit passwords through Google Forms.

# Appendix 4. Questionnaires from the board game

In this appendix, there will be the different questionnaires answered by the seminar's students who took part in the implementation of the board game "In the Loop" for academic purposes.

As it can be detected, there were some students who came from different countries than Italy and they answered the questions in English, rather than in Italian. Nevertheless, they were capable of understanding the content of the questionnaire.

The questionnaires were answered directly in a sheet of paper and, afterwards, the answers were transferred into the digital word version.

# Questionario sul gioco da tavolo “In the loop”

Hai già utilizzato giochi da tavolo o simili come ausilio didattico? No

Se sì, quali?

–

–

In una scala da 1 (nulle) a 5 (elevate), quali sono le tue conoscenze su Economia Circolare (EC) o Ecologia Industriale (EI)? 3

Conoscevi l’esistenza di questo gioco o di altri simili nell’ambito dell’EC o dell’EI?

No

Hai trovato il gioco da tavolo divertente? (1=per niente – 5=molto) 4

Qual è stata la parte, il momento o l’evento del gioco che ti è piaciuto di più?

The moment of choosing a strategy.

Qual è, secondo te, il concetto principale che si ricava dal gioco?

The production system by reusing materials.

Hai imparato qualcosa che non sapevi, grazie al gioco? Cosa?

Yes, the game simulation of a circular economy.

Hai riconosciuto, giocando, qualche strategia tipica dell’EC o dell’EI? Quale/quali?
Yes, the protection of workers in the mining industry.

In che misura il gioco ha cambiato il tuo punto di vista sul riutilizzo/riciclaggio di materiali e prodotti? (1=per niente – 5=molto) 4

Perché? Because I learned from the game how far recycling of materials are under some restrictions.

In che misura il gioco ha cambiato il tuo punto di vista sul commercio di materiali e prodotti (tra organizzazioni oppure tra Paesi)? (1=per niente – 5=molto) 4

Perché? The fact that trading of materials and products are the corner strategy.

Pensi che il gioco sia carente su qualche aspetto dell'EC o dell'EI? Se sì, quali?

Yes, the cycle of production following a logic of sustainability.

Hai qualche suggerimento per il miglioramento del gioco con approcci di EC o EI?

To add aspects related to regulation on environment for the event in play.

Pensi che lo scopo di apprendimento del gioco sia stato applicato correttamente? (1=per niente – 5=molto) 3

Perché? Yes, but with some obstacle added to the final experience.

Pensi che l'uso dell'interazione sociale mediante giochi sia più efficace dell'approccio didattico "tradizionale"? (1=per niente – 5=molto) 4

Lo è in questo campo (EC/EI)? (1=per niente – 5=molto) 4

# Questionario sul gioco da tavolo "In the loop"

Hai già utilizzato giochi da tavolo o simili come ausilio didattico? Yes

Se sì, quali?

Computer games that teach about science through experiments

In una scala da 1 (nulle) a 5 (elevate), quali sono le tue conoscenze su Economia Circolare (EC) o Ecologia Industriale (EI)? 4,25

Conoscevi l'esistenza di questo gioco o di altri simili nell'ambito dell'EC o dell'EI?

Yes, but from the professor

Hai trovato il gioco da tavolo divertente? (1=per niente – 5=molto) 4,5

Qual è stata la parte, il momento o l'evento del gioco che ti è piaciuto di più?

I liked that there were the event cards, which turned our strategies upside down, and that it became clear that commodity prices are set very arbitrary.

Qual è, secondo te, il concetto principale che si ricava dal gioco?

Understanding the dynamics of commodities. There could be more focus on Circular Economy however.

Hai imparato qualcosa che non sapevi, grazie al gioco? Cosa?

Yes, more details on the elements and where they come from (China!) and the arbitrariness of the prices.

Hai riconosciuto, giocando, qualche strategia tipica dell'EC o dell'EI? Quale/quali?
I already knew these strategies.

In che misura il gioco ha cambiato il tuo punto di vista sul riutilizzo/riciclaggio di materiali e prodotti? (1=per niente – 5=molto) 3

Perché? Not too much, we did not use the junkyard too much. I guess in other games the private warehouse is used more.

In che misura il gioco ha cambiato il tuo punto di vista sul commercio di materiali e prodotti (tra organizzazioni oppure tra Paesi)? (1=per niente – 5=molto) 3,5

Perché? As mentioned before, the arbitrary nature of trade was fascinating.

Pensi che il gioco sia carente su qualche aspetto dell'EC o dell'EI? Se sì, quali?

The CE elements only come up in the strategies events. Maybe also the country of production could make a difference.

Hai qualche suggerimento per il miglioramento del gioco con approcci di EC o EI?

Somehow, the EI aspect was not included so much, maybe Industrial Symbiosis could somehow play a role?

Pensi che lo scopo di apprendimento del gioco sia stato applicato correttamente? (1=per niente – 5=molto) 5

Perché? It showed real life dynamics of markets and their constraints.

Pensi che l'uso dell'interazione sociale mediante giochi sia più efficace dell'approccio didattico "tradizionale"? (1=per niente – 5=molto) 3

Lo è in questo campo (EC/EI)? (1=per niente – 5=molto) 4,5

# Questionario sul gioco da tavolo "In the loop"

Hai già utilizzato giochi da tavolo o simili come ausilio didattico? No

Se sì, quali?

–

–

In una scala da 1 (nulle) a 5 (elevate), quali sono le tue conoscenze su Economia Circolare (EC) o Ecologia Industriale (EI)? 2

Conoscevi l'esistenza di questo gioco o di altri simili nell'ambito dell'EC o dell'EI?

No

Hai trovato il gioco da tavolo divertente? (1=per niente – 5=molto) 5

Qual è stata la parte, il momento o l'evento del gioco che ti è piaciuto di più?

Il momento dell'asta e la scelta delle strategie.

Qual è, secondo te, il concetto principale che si ricava dal gioco?

La produzione non sostenibile ha conseguenze non solo ambientali e sociali, ma anche economiche.

Hai imparato qualcosa che non sapevi, grazie al gioco? Cosa?

Molti prodotti nel gioco e dunque indicati dalla Commissione Europea provengono dalla Cina.

Hai riconosciuto, giocando, qualche strategia tipica dell'EC o dell'EI? Quale/quali?
Riciclaggio e riutilizzo di prodotti, mezzi di produzione sostenibili, ad esempio il fotovoltaico.

In che misura il gioco ha cambiato il tuo punto di vista sul riutilizzo/riciclaggio di materiali e prodotti? (1=per niente – 5=molto) 3

Perché? Perché ho la necessità di riciclare per evitare che le riserve si esauriscano o cadano.

In che misura il gioco ha cambiato il tuo punto di vista sul commercio di materiali e prodotti (tra organizzazioni oppure tra Paesi)? (1=per niente – 5=molto) 3

Perché? Ho capito che più le riserve sono limitate più i prezzi del mercato sono alti e dunque la competizione tra imprese e paesi.

Pensi che il gioco sia carente su qualche aspetto dell'EC o dell'EI? Se sì, quali?

Sì, forse mancano delle indicazioni di base per guidare chi non conosce la materia.

Hai qualche suggerimento per il miglioramento del gioco con approcci di EC o EI?

Aggiungerei dei dettagli e delle specificazioni, ad esempio, nella Product o Strategy cards.

Pensi che lo scopo di apprendimento del gioco sia stato applicato correttamente? (1=per niente – 5=molto) 4

Perché? Sì, ma forse qualche spiegazione in più renderebbe il gioco più educativo.

Pensi che l'uso dell'interazione sociale mediante giochi sia più efficace dell'approccio didattico "tradizionale"? (1=per niente – 5=molto) 5

Lo è in questo campo (EC/EI)? (1=per niente – 5=molto) 5

# Questionario sul gioco da tavolo “In the loop”

Hai già utilizzato giochi da tavolo o simili come ausilio didattico? No

Se sì, quali?

–

–

In una scala da 1 (nulle) a 5 (elevate), quali sono le tue conoscenze su Economia Circolare (EC) o Ecologia Industriale (EI)? 2

Conoscevi l’esistenza di questo gioco o di altri simili nell’ambito dell’EC o dell’EI?

No

Hai trovato il gioco da tavolo divertente? (1=per niente – 5=molto) 4

Qual è stata la parte, il momento o l’evento del gioco che ti è piaciuto di più?

Le aste.

Qual è, secondo te, il concetto principale che si ricava dal gioco?

Il modo in cui utilizziamo i materiali può avere delle significative e serie conseguenze sul nostro pianeta.

Hai imparato qualcosa che non sapevi, grazie al gioco? Cosa?

Sì, ho acquisto maggiori conoscenze circa quelli che sono i primi passi da muovere per portare ad un’economia circolare.

Hai riconosciuto, giocando, qualche strategia tipica dell’EC o dell’EI? Quale/quali?
Le mie conoscenze non mi permettono di rispondere approfonditamente.

In che misura il gioco ha cambiato il tuo punto di vista sul riutilizzo/riciclaggio di materiali e prodotti? (1=per niente – 5=molto) 1

Perché? Semplicemente perché è andato a consolidare quanto già penso circa il riutilizzo e riciclaggio dei materiali.

In che misura il gioco ha cambiato il tuo punto di vista sul commercio di materiali e prodotti (tra organizzazioni oppure tra Paesi)? (1=per niente – 5=molto) 4

Perché? Mi sono resa più cosciente circa le modalità di gestione dei materiali critici.

Pensi che il gioco sia carente su qualche aspetto dell'EC o dell'EI? Se sì, quali?

No

Hai qualche suggerimento per il miglioramento del gioco con approcci di EC o EI?

No

Pensi che lo scopo di apprendimento del gioco sia stato applicato correttamente? (1=per niente – 5=molto) 5

Perché? Perché in maniera divertente e alternativa ci ha permesso di entrare maggiormente nell'ottica dell'EC.

Pensi che l'uso dell'interazione sociale mediante giochi sia più efficace dell'approccio didattico "tradizionale"? (1=per niente – 5=molto) 5

Lo è in questo campo (EC/EI)? (1=per niente – 5=molto) 4

# Questionario sul gioco da tavolo “In the loop”

Hai già utilizzato giochi da tavolo o simili come ausilio didattico? No

Se sì, quali?

–

–

In una scala da 1 (nulle) a 5 (elevate), quali sono le tue conoscenze su Economia Circolare (EC) o Ecologia Industriale (EI)? 2

Conoscevi l’esistenza di questo gioco o di altri simili nell’ambito dell’EC o dell’EI?

No

Hai trovato il gioco da tavolo divertente? (1=per niente – 5=molto) 5

Qual è stata la parte, il momento o l’evento del gioco che ti è piaciuto di più?

La produzione.

Qual è, secondo te, il concetto principale che si ricava dal gioco?

La scelta delle strategie di gioco con condivisione di punti di vista e scelte ecologiche.

Hai imparato qualcosa che non sapevi, grazie al gioco? Cosa?

L’esistenza di materie prime rare rinnovabili.

(Si tratta, infatti, di materie prime rare non rinnovabili.)

Hai riconosciuto, giocando, qualche strategia tipica dell’EC o dell’EI? Quale/quali?
Non ne conosco.

In che misura il gioco ha cambiato il tuo punto di vista sul riutilizzo/riciclaggio di materiali e prodotti? (1=per niente – 5=molto) 3

Perché? In realtà il mio punto di vista sul riutilizzo è già estremamente favorevole; il gioco ha sottolineato l'importanza che ha in realtà.

In che misura il gioco ha cambiato il tuo punto di vista sul commercio di materiali e prodotti (tra organizzazioni oppure tra Paesi)? (1=per niente – 5=molto) 4

Perché? Bisognerebbe effettivamente puntare maggiormente su materiali basati su risorse riutilizzabili, alcune delle quali (presenti nel gioco) sono ancora poco conosciute.

Pensi che il gioco sia carente su qualche aspetto dell'EC o dell'EI? Se sì, quali?

Purtroppo non ho le competenze per dirlo.

Hai qualche suggerimento per il miglioramento del gioco con approcci di EC o EI?

Anche in questo non ho le competenze; mi è sembrato un gioco ben strutturato e davvero molto interessante per la condivisione di idee tra ragazzi di campi disciplinari differenti.

Pensi che lo scopo di apprendimento del gioco sia stato applicato correttamente? (1=per niente – 5=molto) 4

Perché? Non do il massimo perché, trattandosi di un gioco di un campo specifico, immagino che chi non sia del campo purtroppo non possa acquisire il senso vero del gioco.

Pensi che l'uso dell'interazione sociale mediante giochi sia più efficace dell'approccio didattico "tradizionale"? (1=per niente – 5=molto) 3

Lo è in questo campo (EC/EI)? (1=per niente – 5=molto) 3

# Questionario sul gioco da tavolo "In the loop"

Hai già utilizzato giochi da tavolo o simili come ausilio didattico? No

Se sì, quali?

–

–

In una scala da 1 (nulle) a 5 (elevate), quali sono le tue conoscenze su Economia Circolare (EC) o Ecologia Industriale (EI)? 4

Conoscevi l'esistenza di questo gioco o di altri simili nell'ambito dell'EC o dell'EI?

Sì

Hai trovato il gioco da tavolo divertente? (1=per niente – 5=molto) 5

Qual è stata la parte, il momento o l'evento del gioco che ti è piaciuto di più?

Riflettere sulle strategie.

Qual è, secondo te, il concetto principale che si ricava dal gioco?

Che non c'è mai una soluzione ottimale per tutti i campi e il momento storico pesa notevolmente nelle scelte.

Hai imparato qualcosa che non sapevi, grazie al gioco? Cosa?

Che molti elementi sono disponibili in Cina.

Hai riconosciuto, giocando, qualche strategia tipica dell'EC o dell'EI? Quale/quali?
Vendita del servizio e non del prodotto.

In che misura il gioco ha cambiato il tuo punto di vista sul riutilizzo/riciclaggio di materiali e prodotti? (1=per niente – 5=molto) 2

Perché? Conoscevo già molte delle strategie.

In che misura il gioco ha cambiato il tuo punto di vista sul commercio di materiali e prodotti (tra organizzazioni oppure tra Paesi)? (1=per niente – 5=molto) 4

Perché? Le variabili che potrebbero presentarsi sono numerose e non consentono di applicare le strategie adottate.

Pensi che il gioco sia carente su qualche aspetto dell'EC o dell'EI? Se sì, quali?

No

Hai qualche suggerimento per il miglioramento del gioco con approcci di EC o EI?

Si potrebbero riportare delle definizioni (anche semplici) delle varie strategie per far comprendere al meglio i concetti di EC e EI.

Pensi che lo scopo di apprendimento del gioco sia stato applicato correttamente? (1=per niente – 5=molto) 5

Perché? Perché il gioco illustra la complessità dei meccanismi economici e le problematiche sociali e ambientali.

Pensi che l'uso dell'interazione sociale mediante giochi sia più efficace dell'approccio didattico "tradizionale"? (1=per niente – 5=molto) 5

Lo è in questo campo (EC/EI)? (1=per niente – 5=molto) 5

# Questionario sul gioco da tavolo “In the loop”

Hai già utilizzato giochi da tavolo o simili come ausilio didattico? No

Se sì, quali?

–

–

In una scala da 1 (nulle) a 5 (elevate), quali sono le tue conoscenze su Economia Circolare (EC) o Ecologia Industriale (EI)? 4

Conoscevi l’esistenza di questo gioco o di altri simili nell’ambito dell’EC o dell’EI?

No

Hai trovato il gioco da tavolo divertente? (1=per niente – 5=molto) 5

Qual è stata la parte, il momento o l’evento del gioco che ti è piaciuto di più?

L’asta per acquistare i materiali e il momento dell’”evento”.

Qual è, secondo te, il concetto principale che si ricava dal gioco?

Imparare ad adottare strategie aziendali sostenibili calibrando le scelte.

Hai imparato qualcosa che non sapevi, grazie al gioco? Cosa?

Sì, conoscere alcuni elementi necessari per produrre determinati prodotti.

Hai riconosciuto, giocando, qualche strategia tipica dell’EC o dell’EI? Quale/quali?
Ecodesign, produrre prodotti verdi…

In che misura il gioco ha cambiato il tuo punto di vista sul riutilizzo/riciclaggio di materiali e prodotti? (1=per niente – 5=molto) 2

Perché? Non è fortemente incentrato sul riutilizzo dei materiali.

In che misura il gioco ha cambiato il tuo punto di vista sul commercio di materiali e prodotti (tra organizzazioni oppure tra Paesi)? (1=per niente – 5=molto) 1

Perché? Non ha modificato il mio punto di vista.

Pensi che il gioco sia carente su qualche aspetto dell'EC o dell'EI? Se sì, quali?

No

Hai qualche suggerimento per il miglioramento del gioco con approcci di EC o EI?

No

Pensi che lo scopo di apprendimento del gioco sia stato applicato correttamente? (1=per niente – 5=molto) 3

Perché? È istruttivo, consente di conoscere alcuni materiali necessari per produrre prodotti utilizzati quotidianamente.

Pensi che l'uso dell'interazione sociale mediante giochi sia più efficace dell'approccio didattico "tradizionale"? (1=per niente – 5=molto) 5

Lo è in questo campo (EC/EI)? (1=per niente – 5=molto) 5

# Questionario sul gioco da tavolo "In the loop"

Hai già utilizzato giochi da tavolo o simili come ausilio didattico? No

Se sì, quali?

–

–

In una scala da 1 (nulle) a 5 (elevate), quali sono le tue conoscenze su Economia Circolare (EC) o Ecologia Industriale (EI)? 1

Conoscevi l'esistenza di questo gioco o di altri simili nell'ambito dell'EC o dell'EI?

No

Hai trovato il gioco da tavolo divertente? (1=per niente – 5=molto) 4

Qual è stata la parte, il momento o l'evento del gioco che ti è piaciuto di più?

La produzione dei prodotti.

Qual è, secondo te, il concetto principale che si ricava dal gioco?

La gestione dell'economia nella produzione.

Hai imparato qualcosa che non sapevi, grazie al gioco? Cosa?

E' importante gestire diversi aspetti all'interno della produzione.

Hai riconosciuto, giocando, qualche strategia tipica dell'EC o dell'EI? Quale/quali?
Non lo so, perché non ho le conoscenze.

In che misura il gioco ha cambiato il tuo punto di vista sul riutilizzo/riciclaggio di materiali e prodotti? (1=per niente – 5=molto) 3

Perché? Non ho percepito molti incentivi nell'utilizzo di prodotti green.

In che misura il gioco ha cambiato il tuo punto di vista sul commercio di materiali e prodotti (tra organizzazioni oppure tra Paesi)? (1=per niente – 5=molto) 4

Perché? Ho capito che la disponibilità dei materiali ricade molto sulla produzione.

Pensi che il gioco sia carente su qualche aspetto dell'EC o dell'EI? Se sì, quali?

Non lo so.

Hai qualche suggerimento per il miglioramento del gioco con approcci di EC o EI?

Forse andrebbe migliorato l'utilizzo della private warehouse.

Pensi che lo scopo di apprendimento del gioco sia stato applicato correttamente? (1=per niente – 5=molto) 5

Perché? Ha suscitato in ogni giocatore apprensione e volontà di raggiungere gli obiettivi.

Pensi che l'uso dell'interazione sociale mediante giochi sia più efficace dell'approccio didattico "tradizionale"? (1=per niente – 5=molto) 4,5

Lo è in questo campo (EC/EI)? (1=per niente – 5=molto) 4